AGRICULTURAL AND FOOD RESEARCH ISSUES AND PRIORITIES

A Review and Assessment

UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
THE NATIONAL ASSOCIATION OF
STATE UNIVERSITIES AND
LAND-GRANT COLLEGES

This review and assessm arch issues and
priorities was done at t esearch Policy
Advisory Committee (ARP/ ns to review,
assess, summarize, and c ber of reports
and events of particula ural research.
The report was reviewed It was also
reviewed by the Executi on Food and
Agricultural Sciences in be published.

A diverse array of impo ed issues are
summarized and interpret his report.
This, plus the objective ritics and
advocates of the present presented,
adds greatly to the valu primarily for
administrators, policy m her science
and education leaders th al system.

Some statements in this views and
policies of the U.S. Dep

I am pleased to present half of ARPAC,
the Joint Council, the N versities and
Land Grant Colleges, and the U.S. Department of Agriculture.

ANSON R. BERTRAND
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December 1978

AGRICULTURAL AND FOOD RESEARCH
ISSUES AND PRIORITIES

A REVIEW AND ASSESSMENT

A Report on

The Findings and Recommendations Contained in Conference Proceedings, Congressional Hearings, Special Studies, Articles, and Other Published Reports and Materials Dealing with Agricultural and Food Research Policy and Performance.

PREFACE

At its October 28, 1976, meeting, the Agricultural Research Policy Advisory Committee (ARPAC) instructed its National Planning Committee (NPC) to initiate policy guidance and strategic planning efforts involving the publicly supported agricultural research system for the purpose of assisting ARPAC in the execution of its policy development and research planning and coordination responsibilities. On December 15, a two-person team was appointed to staff the initial effort and to work with a newly appointed policy guidance and oversight group. The charge to the team and group was to review and assess recent studies, reports, and principal events of special importance to agricultural research and to summarize the results in a brief report. The two-person team consisted of E. L. Corley, representing USDA, and James Turnbull, representing the State Agricultural Experiment Stations (SAES). The team was assisted by Risë Pennell (USDA) who handled the administrative, editorial, and secretarial tasks necessary to the report's preparation and finalization.

Given the vast amount of information generated over the past few years, and notably since the onset of the "World Food Crisis," the team chose to focus on issues, options, and recommendations of special importance to agricultural research. The approach taken was designed to produce a report that would reflect the prevalent issues and recommendations for which there appears to be consensus, document these as objectively as possible, and provide the basis for strengthening existing food and agricultural research programs and policies.

This led to a detailed report containing many quotations but one relatively free of interpretation and assessment. The "Interpretive Summary," on the other hand, is based on the authors' interpretation of the prevailing views in the full report.

Three major events of relevance to the content of this report have occurred since the preparation of this report. The National Research Council, National Academy of Sciences (NAS), published a World Food and Nutrition Study in June of 1977, in which they assess the problem of hunger and malnutrition and develop specific recommendations on how U.S. research and development capabilities can best be applied to meeting the challenge of providing adequate diets to all people.

A review of the NAS study was conducted by USDA and State officials at the request of ARPAC. The NAS and Corley-Turnbull reports were compared and the recommendations examined. It was concluded that "...there were no fundamental conflicts in recommendations and there were many points of agreement" ..."the reports surveyed by Corley and Turnbull specifically identified all of the 22 priority areas...except (1) policies affecting nutrition, (2) nutrition intervention programs, (3) trade policy, (4) food reserves, and (5) information systems."

A second major event was the passage of the Food and Agriculture Act of 1977 in which, under Title XIV - National Agricultural Research, Extension, and Teaching Policy Act of 1977, the U.S. Department of Agriculture was designated

as the lead Federal Agency for food and agricultural science. Food and agricultural science is broadly defined to include all matters normally associated with the food and agriculture system plus forestry, range management, aquaculture, family life, and rural and community development. The provisions involve increased emphasis on coordination, establishing priorities, and widening participation in research and education beyond the USDA and Land Grant University system.

Coordination will be aided by a newly formed Joint Council on Food and Agricultural Sciences. Also, a new National Agricultural Research and Extension Users Advisory Board has been formed to provide independent advisory opinions on the food and agricultural sciences.

A third major event was the reorganization of research and education in the U.S. Department of Agriculture in 1978. Under the new organization, in-house research, cooperative research, extension, higher education, and technical information were consolidated into a single Science and Education Administration (SEA) under the Assistant Secretary for Conservation, Research, and Education.

These major events, which occurred since the completion of the subject study in April 1977, are noted here to provide the reader with an up-to-date view on food and agricultural research issues and priorities.

The present report "Agricultural and Food Research Issues and Priorities--A Review and Assessment" was approved by ARPAC in August 1977, and endorsed by the Joint Council on Food and Agricultural Sciences in July 1978, which recommended that it be published, in view of its significant contribution as a review and assessment of food and agricultural research issues and priorities.

This then is the report as it was prepared in April 1977.

E. L. Corley
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December 1978

INTERPRETIVE SUMMARY

Food and Agricultural Research as a National Issue

The world food crisis of 1972-75 elevated food and agriculture as national and world issues. This crisis spawned a host of conferences, special studies, hearings, and debates. The general tone of these and other views indicates food and agriculture is a critical issue when viewed internationally and in the long term. The uncertainty of adequate food supplies beyond 1985 is a fact of life with little time for significant new research starts to have a major impact on production.

There is a general consensus that world population will continue to increase well into the 21st century regardless of how effective population control measures may be. Incremental increases in food and fiber production are expected to continue as a result of ongoing research programs, but major breakthroughs of the potential impact of hybrid corn are not presently in sight. Many feel that the anticipated incremental increases in agricultural productivity will not be adequate to meet the increased demands of an expanding world population, and for continued improvements in health, safety, and the environment. Development and acceptance of nonconventional sources of protein, such as yeast, fungi, green leaf extracts, and chemical synthesis, are at least 20 years away. The most reliable and cost effective ways to assure food and fiber supplies, which will be adequate to meet U.S. and world needs by 1985 and beyond, are more rapid development and adaptation of new technology to increase production of conventional crops and animals. This, in turn, depends on a level of research that is adequate to provide the basis for the required new technology. At present, our reserves of technology and new knowledge are being consumed faster than they are being replenished. There is a consensus that we must increase the rate at which we are making advances in agricultural research in order to at least maintain, and preferably to increase, the reservoir of knowledge.

Some feel the U.S. and the world face an awesome alternative. If we fail to find the needed research breakthroughs and develop the related technology, a widening gap will develop between food supplies and worldwide food needs. At best, this will result in increased hunger in the world. At worst, we could have massive famine and starvation. As demand exceeds supply, the world will face sharply increased food prices, inflation, and social and political instability.

Despite these concerns, food and agricultural research has not gained "national issue" status in the perspectives of many policymakers. If agricultural research deserves higher priority, as most reports suggest, the absence of consensus on its importance by policymakers results in part from failure to identify and articulate the underlying issues and justifications in an effective way and in a timely manner. One such issue is the lack of understanding of the long-term requirements of fundamental research. Another, some feel, is the absence of adequate, comprehensive, and fully integrated state, regional, and national research programs and a strategy for their implementation, coordination, and management.

Strengths of the Present Agricultural Research System

Many reports reviewed describe the scope, coordination, and strengths of the present public agricultural research system and its responsiveness to changing needs of society. Its similarity to the U.S. research and development system in general is noted, as well as the strengths gained from the pluralism in its organization, management, and support systems. It has responded well to diverse problems throughout the world and provides a tested and integrated model of fundamental, applied, and developmental research and technology transfer to public use.

The purpose of most of the reports reviewed was to address food and agricultural needs, priorities, policies, and to offer possible ways to improve the supporting research system. The recommendations for change were in terms of strengthening programs and policies rather than for major overhaul or dismantling. The present report, being a summary of approximately 50 reports and studies completed in recent years, largely reflects the tone and scope of prior reports, some of which were critical of the present system. However, it is important to note that <u>virtually every critic also applauds the current and past performance of the publicly supported food and agriculture system</u>.

It is also important to note that the present study was intended to capture the major issues, concerns, and recommendations made in previously conducted studies and reports and not to defend or justify the present system. Therefore, the strengths of the present system are covered only briefly. Major strengths include (1) an integrated system of basic and applied research with a highly effective delivery system through extension programs, (2) a system that combines good qualities of decentralization--such as adaptive research specific to needs at locations, and centralization--such as research on highly contagious diseases like Foot and Mouth Disease in cattle, (3) productivity gains in agriculture and forestry, (4) high returns on investments, and (5) a State-Federal-industry partnership.

Much has been written about the strength of the State-Federal-industry partnership which has been an essential part of the food and agriculture success story for more than a century. This partnership has been especially effective at the scientist level.

The scope, organization, and dispersion of the system provide continuing challenges for improvements in coordination, joint planning, and documentation. Complexities are reflected by the variety of funding sources for, and the diversity of performers of food-related research in the U.S. One report identified 10 <u>funding</u> agencies for food-related research in fiscal year 1976. This included 47 percent by Federal agencies, 32 percent by private industry, 18.5 percent by State universities, and 2.5 percent by other sources. Food-related research <u>performers</u> were private industry, 31 percent; Federal laboratories, 29 percent; SAES and Colleges of 1890, 28 1/ percent; non-SAES universities, 8 percent; and other, 4 percent. Total funding of food-related

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1/31 percent according to figures from ARPAC publication of November 1976.

research in the U.S. was reported to be $1.2 billion. USDA received 54 percent of the total Federal appropriation and conducted 67 percent of the food-related research done in Federal laboratories.

Concerns About Research Organization and Management

The criticism of the organization and management of the present system emphasizes fragmentation or lack of concentration of effort; isolation or a system that is too closed to policy guidance, advice, contributions from and dialogue with the rest of the science and technology community; inadequate input from users of research and from consumers; and absence of a "lead agency" role for research and education in support of food and agriculture. Many agreed with Wittwer's comments that "There is not a single body which provides a focal point for technical guidance, coordination, and facilitation of this immensely complex endeavor." Such views appear to be behind several bills now before the 95th Congress that would provide for policy, operations, and advisory oversight and coordination at the national level.

The fragmentation issue is difficult to assess. While agencies and institutions respond to a wide range of needs and pressures, there may be more fragmentation and less concentration than is desirable. It may be that the research planning process would be aided by guidelines, which establish program areas of special emphasis and their assignment to specific specialized and qualified R&D organizations or groups to the extent that mutual agreement can be reached among the agencies and institutions involved.

A "lead agency" role does appear to be needed, not only in "traditional" areas of research but also for research on energy, human nutrition, natural resources, aquaculture, weather and climate, and technical assistance to developing countries.

Concerns About Research Coordination

Coordination of research in the U.S. and internationally received much attention in the reports reviewed. Clearly, the challenge is tremendous given the complexities of organization, objectives, programs, and legislative processes. Key words and phrases used to express these concerns are duplication, lack of unifying program structure, use of ad hoc techniques, coordination at national level, etc. Recommended improvements include a more effective policy and priority-setting apparatus for food and agricultural research, and a more effective interface in policy development with such key agencies as AID, HEW, DoD, NSF, and others.

Coordination implies mutual agreement and cooperation among equal partners. The need for coordination should be addressed judiciously so as to encourage closer relationships, greater trust and respect, and full exchange of information.

There are indications that coordination among scientists is more effective than coordination among organizations.

Concerns About Food and Agricultural Research Policy

Inadequate food and agricultural research policy is one of the most prevalent themes in these studies. However, the same concern has been expressed about science and technology policy at large, concern that has led to establishment of the Office of Science and Technology Policy (OSTP) and recommendations for a President's Committee on Science and Technology. A "call" for a "clearly dynamic national policy for agriculture research" has appeared repeatedly. Policy and advisory councils have been proposed. The need to draw more on the views of consumers and nonagricultural interests in setting policy has been emphasized. "Outside" groups are demanding a voice in determining research priorities and emphasis. There are questions as to who is and should be the clientele for agriculture R&D results.

Suggestions which have been made to the Department and the State Agricultural Experiment Stations include the following options: (1) clarify and restate existing and develop improved research policy by the Department, (2) establish a Presidential level committee on National Food and Agriculture Research Policy, (3) support OSTP in their development of an overall S&T policy, or (4) look to legislation by Congress and/or action by the White House for leadership in policy determination.

It should be noted that some authorities feel the present policy, while broad, provides a sound framework around which policy decisions can adapt very well.

The authors feel that the Department should take the lead in clarifying, developing, and restating national policy for agricultural research and that supportive action by other agencies and branches of government is needed, given the complexities and interactive forces involved in the formulation and management of agricultural policy.

Strengthen the Review, Evaluation, and Justification of Ongoing Research Programs

Some form of stringent periodic reviews of all federally funded research programs such as zero-base budgeting is imminent. USDA agencies must develop the means to meet these requirements including procedures for enabling the State institutions receiving Federal-grant support to participate more fully in the budgetmaking process. Program structures must reflect the need for a unifying framework for planning, management, coordination, review, assessment, and budget development. Base programs must be defended more rigorously by use of *ex post* and *ex ante* analysis, indicators of progress, and expressions of what would result if present and planned research is not done. In conjunction with these efforts, guidelines should be established for roles, functions, and "lead" areas of responsibility for USDA agencies, the SAES, and other research and educational institutions and groups.

Inadequate Funding

Nearly all reports reviewed recommended increased funding levels to meet current demands. Inadequate science and technology reserves, inflationary costs, increased demands for environmental quality and food safety, inadequate facilities, research needs to meet requirements of action and regulatory

agencies and their policies, and the small share of the Federal research and development budget devoted to food and agriculture all bear testimony to the need for additional funding. However, OMB and others still do not give agricultural research and development high priority. In the short run, a carefully developed rationale for significant increases in food and agricultural research is needed, including consensus views on priorities and general implementation strategies. Over the long run, comprehensive, coordinated national research plans, policies, and programs are needed, including specific implementation plans and strategies for all of food and agriculturally related research. It is possible that improved assessment and evaluation results will lead to higher priority for food and agricultural research.

Implementation Strategies

The publicly supported agricultural research system has been under critical review and study on a continuing basis for the past decade. Emphasis has been given to all phases of organization, coordination, management, quality of work, program needs, and research priorities. These studies, including considerable testimony before Congress, bear evidence that this system, while complex, diverse, and difficult to adminster is dynamic and responsive to changing needs of society. Constructive recommendations have been made for improvement and corrective action has already been taken in response to many of the suggestions. There appears to be general consensus on research priorities. More than ever before, there appears to be general agreement on key issues. The end result is a wealth of good information about all aspects of the present system, including its performance. What appears to be missing is a strategy policymakers can use to translate these findings into improved (a) food and agricultural policies, and (b) more fully supported programs of research.

Research Program Areas of Special Concern

Several comprehensive studies give focus to food and agricultural priorities. These needs are summarized in this report. Several reports stress obsolescence and general inadequacy of existing R&D facilities in the publicly supported system, and the need to strengthen ongoing programs to combat losses resulting from inflation and increased research costs. Research receiving most frequent emphasis for strengthening and added funding include selected aspects of the following areas which are discussed more fully in following sections of the report:

- -- Basic biological processes
- -- Environmental protection and food safety
- -- Human nutrition and food quality
- -- Pest control
- -- Energy conservation and use
- -- Production efficiency
- -- Processing, storage, distribution, and delivery systems
- -- Natural and renewable resources
- -- Weather and climate
- -- Aquaculture
- -- Labor-intensive research for U.S. and developing countries
- -- Policy analysis and monitoring of system performance

There is considerable emphasis in this summary, and particularly in the following discussion of research program areas, on world food needs and on research required to meet these needs. The general feeling expressed in the reports reviewed is that the U.S. must develop a total agricultural research program which considers not only research directed at meeting increased domestic requirements for food and fiber but also recognizes the need for research to increase production for export and the urgency of research on how to transfer and adapt new technology to the needs of the developing countries.

There is also considerable emphasis on the need to up-date and/or replace research facilities which are obsolete, inefficient, overcrowded, or otherwise unsuitable for today's sophisticated research approaches, and thereby unable to make maximum contribution to a fully effective research program.

Basic Research

Throughout the reports reviewed, there is a general concern that we are not devoting enough effort to basic research. There is a corollary conviction that major breakthroughs in basic research are necessary to provide for the essential increases in crop and animal production which will be needed to provide for the food and fiber needs of the world in the decades beyond 1985.

Three areas of basic research are singled out in several reports as being particularly in need of intensified effort and having a high probability of significant payoffs in terms of increased food production:

a) Photosynthetic carbon dioxide fixation by the green plant through the bioconversion of solar energy
b) Biological nitrogen fixation
c) Genetic splicing and related cell and tissue culture

While these three areas are mentioned most frequently, there is also general recognition of the need for expanded basic research in other areas of plant and animal science. One such area is the physiological and biochemical processes involved in reproduction and performance traits in farm animals. Another is for a better understanding of the biological processes in pest control for crops.

Basic research in all of these areas offers an opportunity to draw on the skills and training of scientists both inside and outside of the traditionally agriculturally oriented disciplines. There are also alternatives for both centralization and decentralization of various aspects of research in these areas and for the development of research teams for more effective conduct of the research. The wider use of competitive grants for funding of basic research is suggested in several reports.

Research to Protect the Environment and Assure Food Safety

Another area of research which is receiving an increasing amount of attention is that required to meet the growing governmental and public awareness in protecting the environment. There is concern that funds and scientific effort needed for productivity-increasing research or for development of new products or processes are being reassigned to research related to meeting specific

restrictive laws and regulations affecting the use of land, water, labor, equipment, chemicals, and plant varieties, and what some consider to be excessive testing for safety, toxicology, and quality control. The concerns expressed are not with the need for this type of research, but with balancing the requirements for environmental enhancement with those of other aspects of the total agricultural research program, and in particular, with the need to increase productivity.

There are indications that because of the regulatory needs for additional research related to quality control, private industry may devote less of its R&D support to the development of new products and new processes. The extent to which public research should expand in this area is not clear at this time.

Human Nutrition

It has been said that, "Current knowledge of nutritional requirements is more complete for poultry, cattle, sheep, and swine than it is for humans." In the developing countries, the principal problems of improved nutrition are how to provide adequate calories and proteins. In some of the lesser developed countries, there are acute public health nutritional problems, such as vitamin A deficiency (causing blindness), iron and folic acid deficiency (causing anemia), and iodine deficiency (causing goiter). As a National Academy of Sciences report points out, however, "The United States is itself scarcely a model for the development of national nutrition policies and programs." Nutrition research has been categorized as being at a "primitive level." USDA efforts to obtain greater support for nutrition research over the past several years have been unsuccessful.

There are overlapping and confusing responsibilities between USDA and HEW, and there has been "a reluctance to develop a clearly defined national nutrition research policy."

There are mixed views on the potential for nonconventional and novel sources of protein such as yeast, bacteria, and fungi, and the role "traditional" agriculture should play in such research. Energy shortages and costs, legal and regulatory barriers, including USDA and FDA standards and procedures, political and institutional constraints to introduction and commercialization of new protein foods, and problems relating to marketing of new food products must be met if new protein foods are to be introduced.

There is general agreement that, "Human nutritional research should focus on problems of energy (calories) and protein requirements for different sexes, sizes, ages, and activity levels in different climates; the relative values of carbohydrates and fats as energy sources, and the relationship of quantities consumed to human health, metabolic individuality of different peoples; development of clinical indices of nutritional status, particularly for children; and the interrelationship among poverty, malnutrition, and disease." Other areas of broad agreement include the need to develop criteria for establishing nutrient requirements and the interrelationships of nutrients and other food components.

Pest Control Research

Some of the greatest losses in agricultural production, storage, and shipment are those associated with pests. Weeds compete with crops for nutrients, moisture, and sunlight. Insects damage or destroy both growing plants and harvested plant products and limit animal growth and/or productivity. In addition, insects serve as vectors of diseases that afflict plants, livestock, fish, and humans. Rodents consume or destroy large quantities of agricultural products. It has been estimated that "one-third of the U.S. annual harvest is destroyed by pests" [8] and that further losses from pests occur during storage. The losses in lesser developed countries are even greater.

Specific areas needing intensified research include: (1) integrated pest management systems utilizing cultural, genetic, and conventional chemical techniques, (2) selective biologically based interference with the reproductive processes of the pest species, (3) microbial and natural biological agents for pest control, and (4) breeding for pest resistance.

Energy Research

Agriculture in the United States is heavily dependent on energy. It is estimated that crop and livestock production requires about 3 percent of our total energy use, and that the entire U.S. food system (production, processing, distribution, preparation) uses 12 to 17 percent of the total energy consumed nationally. In the developing countries, higher costs for fertilizer and agricultural chemicals, both extensive users of energy, may have significant effects on total agricultural production and on cropping systems.

The National Task Force on Agricultural Energy categorized energy R&D into three main groupings: "(1) Conservation and use of energy in production, processing, marketing, and consumption of crops, livestock, and forest products; (2) substitution by renewable or noncritical energy sources and forms which include use of biomass for energy production; use of solar, wind, and geothermal energy; use of coal, lignite, oil shale, peat, and electricity; use of waste heat from power plants and other sources; (3) physical and socioeconomic consequences which deal with alternatives for energy production availability and use, including the impact on natural resources."

Basic research on increasing the photosynthetic conversion of solar energy and on biological fixation of nitrogen is essential to any comprehensive program of research on energy both because of increased efficiency of crop production and reduced use of nitrogen fertilizer.

There is general agreement that the full impact of the energy problem has not yet been felt, and that there is urgent need for additional research in this area. The world's supply of natural gas may be exhausted before the end of the century, and restrictions have already affected agriculture. There is worldwide concern about oil supplies and urgent need to conserve the world's limited oil resources. Even coal, which is abundant in this country, is not inexhaustible, and environmental considerations impose limitations on both mining and use of coal. Agricultural lands may soon be needed to produce crops which will provide alternative or supplementary energy sources to natural gas and fossil fuels. It is clear that agriculture and forestry have

key roles to play in developing energy conservation practices, in the search for new sources of energy, and in adapting the present food and fiber systems to changing energy sources.

Production Efficiency Research

There is general agreement on the need for increased crop and animal production and on the need for research required to accomplish this increase in production. In the U.S. alone, we will need one-third more food by the year 2000, without considering export requirements.

Meeting world food requirements depends largely on what happens to seven major crops: wheat, rice, maize, soybeans, sugar, potatoes, and pulses. Some aspects of basic plant research and the need for more effective insect and pest control have already been cited. In addition, to meet both U.S. and world needs, the following recommendations concerning plant science research have been made in the reports reviewed: (1) Strengthen research support for the basic plant sciences, (2) intensify and expand international efforts to preserve, conserve, and exchange genetic resources, (3) broaden the range of parameters in plant breeding research, (4) develop more efficient methods of crop fertilization, (5) accelerate work on conventional breeding for higher and more dependable yields, (6) develop a variety of intensive cropping systems for the tropics, and (7) increase the protein value of grain.

The U.S. is a net importer of livestock products and needs additional research aimed at meeting increasing domestic requirements. There is need for an expanded livestock industry in the U.S. and in some of the developing countries to utilize the forage which represents the most effective use of specific soils and climates. The principal production problem in developing countries is low yield of animal products rather than insufficient animal numbers. Limiting factors in these countries are feed, diseases, low reproduction efficiency, and inadequate access to markets.

Specific livestock research areas identified as having significant potential for increased production both in the U.S. and developing countries include: (1) control of reproductive and respiratory diseases, (2) developing genetically superior animals, (3) improving nutrition efficiency, and (4) increasing the reproductive performance of all farm animal species.

Processing, Storage, Distribution, and Delivery Systems Research

With the possible exception of production losses, those losses associated with the processing, storage, distribution, and delivery of agricultural products are the most serious in the entire chain from planting to consumption. "In many countries, post-harvest losses of certain food crops, if held long in storage, may reach 50 percent." Losses in the U.S. are much less but firm estimates are not available. Research emphasis is needed on (1) reducing losses of raw products, (2) reducing losses of prepared products, (3) improved standardization of packaging systems, (4) development of a more detailed national transportation plan as it affects agriculture, (5) improved food technology (with emphasis on low-energy systems, cost of sanitation, food wastes, cost of delivery, and water requirements in processing), (6) improved food safety (with emphasis on ways to detect, handle, and avoid contaminants;

chemical and physical methods of detoxifying mycotoxins; and methods for testing, detecting, and controlling natural toxicants), (7) education research for food delivery systems, and (8) development of alternative methods of delivery to reduce transportation and storage requirements with special emphasis on reducing refrigeration needs and spoilage.

Natural and Renewable Resources Research--Land and Water

Increased food production, particularly in the developing countries, depends heavily on wise use of soil and water resources. New lands can be brought into cultivation, particularly in Africa and South America, if problems of low fertility, high acidity, erosion, and unfavorable water relations can be overcome.

In irrigated areas throughout the world, problems of salinity, waterlogging, and water quality are dominant. In spite of high costs and energy consumption, falling groundwater levels, and overappropriation of surface waters, irrigation will continue to play a major role in crop production worldwide. In the U.S., one-fourth of the total gross farm receipts come from the 10 percent of the land that is irrigated. For the world as a whole, water is a limiting factor in food production on more than 1.4 billion hectares of nonirrigated land. There is no effective inventory of total water resources either in the U.S. or in developing countries.

Erosion is also a worldwide problem. As late as 1965, nearly two-thirds of the nonfederal land in the U.S., which has the best soil resources of any country, still needed some kind of conservation practice. We have a partial inventory of land resources in the U.S. but essentially none in the developing countries.

Specific research areas requiring emphasis are: (1) water policies and laws, (2) water quality, conservation, and use, (3) soil resource appraisal and allocation, (4) soil management, (5) soil fertility, (6) soil erosion, (7) soil pollution, (8) farming low precipitation areas for maximum production, (9) use and management of rangelands, and (10) cropping systems to make most effective use of water.

Natural and Renewable Resources Research--Forestry

Forests represent a renewable resource which can be used for housing and other structural purposes, paper and paperboard, textiles, chemical feedstocks, and fuel. Forests also provide unique recreational opportunities and food and shelter for wildlife.

Forest products can be used in substitution for or to augment scarce or costly nonrenewable resources. There is need for additional emphasis on research to increase the supply of materials from existing forests and to increase our knowledge of wood science and technology. The development of improved procedures for manufacturing structural materials from wood flakes, strands, veneer, fiber, and other wood products or by-products, and the more effective use of forest products for various chemical and energy purposes are particularly timely research areas.

Increased emphasis is also needed on economic and social studies, particularly on the influence of institutional barriers on the balance of trade in wood and on the more effective use of forests for recreation and wildlife habitat.

Weather and Climate

A major cause of variation in food and fiber production is the fluctuation of weather and climate. Research on weather and climate could have a significant effect on improving plant and animal production. Unusual patterns of rainfall and snowfall recently have led to unprecedented drought conditions in Western Europe and in parts of the U.S. In other parts of the U.S. excessive precipitation has delayed planting and/or created poor growing and harvesting conditions. Intensive research is needed to enable farmers to cope more effectively with periodic and cyclic extremes in precipitation, which have devastating effects on food and fiber production. A fuller understanding is needed how weather, climate, crops, pest, and pest control interact. Applied research is needed to adapt existing basic knowledge to programs of weather modification and food and fiber production.

Research is particularly needed (1) to develop more effective long and short range weather predictive capability so that farmers can plan their crop and animal activities more effectively, (2) to limit damage from hail by improved hail suppression techniques, (3) to limit other crop and animal losses associated with, or exacerbated by specific weather conditions, and (4) to provide, through weather modification, a more adequate amount and distribution of rainfall for better growing conditions.

The legislative authority of USDA to participate in some of this research is not clear. However, USDA and SAES have expertise in related areas such as remote sensing, agricultural meteorology and climatology, and relationship of climate and stress variables to crop yields and quality.

Aquaculture

Aquaculture, the cultivation of fish species, offers an opportunity to considerably increase food production. Naturally occurring or manmade ponds can be used to produce a high-protein food crop on areas which might otherwise be nonproductive. In some cases, culture of fish and shellfish is or can be integrated into more traditional production systems such as rice production. Research in aquaculture is needed in developing fish culture and management techniques to maximize yields, in breeding and selection, in nutrition, and in disease control.

The legislative authority of the USDA to participate in research related to aquaculture is vague and difficult to adminster. The State Agricultural Experiment Stations, under somewhat broader authority, are conducting a limited program of research on aquaculture.

Labor Intensive Research for U.S. and Developing Countries

The problem of world food supply and the means by which the developing countries increase the productivity of their agricultural systems to meet their food requirements is only incidental to the scope of this report.

To do justice to these complex problems would require a separate study and report at least comparable in scope to this report. However, a few observations are in order. It is generally agreed that the bulk of the increase in food supply for the developing countries must come from increased production in those countries. Except for some of the less densely populated areas of Latin America and Africa, the increases must come from intensified agriculture and the use of improved methods to increase annual yields on land already under cultivation. It is also generally recognized that present U.S. technology and "know-how" cannot be transferred directly to developing nations on an extensive basis.

Present legislation and/or legislative policy generally restricts USDA research agencies to research directly affecting U.S. agriculture. Similarly, the Hatch Act, which provides Federal grant funds to the SAES, has been interpreted as limiting the use of these funds to research directly benefiting U.S. agriculture. By implication, the restrictions of the Hatch Act have been extended to other Federal grant funds administered by the Cooperative State Research Service.

Exceptions to these general restrictions are the Special Foreign Currency Research Program under PL 480 and the Tropical and Subtropical Agricultural Research Program under Section 406 of the Food for Peace Act of 1954. Both programs are quite limited, both in funding and in scope.

Problems of overlapping or conflicting responsibility between AID and USDA appear to be obstacles to both adequate funding and more effective participation of USDA in providing research to meet the needs of developing countries. Title XII of the International Development Food Assistance Act of 1975 offers promise for bringing the research capabilities of U.S. universities to bear on the research needs of the developing countries.

There is renewed interest in the U.S. in the problems of small farms, part-time farmers, and home gardeners. Some of the work in this area, which is largely labor-intensive, could be of direct value to developing countries. However, social, economic, political, and educational constraints to technology transfer are serious and continuing.

Policy Analysis and Monitoring of System Performance

Previous sections of this report have addressed primarily the plant, animal, and natural resource aspects of research to increase or maintain food and fiber supplies. A total program of research would not be complete, however, without emphasis on those social and economic research needs which are essential to improved production and marketing systems, to more effective use of human and natural resources, to more effective policies for sound rural area development, and to greater consumer satisfaction. Such research is an important component of many of the research areas already discussed.

There are significant needs for additional research in public policy, both domestic and international; finance; human resources; rural development; and social institutions.

Policy Areas Requiring Action

The USDA should assume the lead Federal agency role in food and agricultural research and formulate and support a more visible food and agricultural research policy. This role should be performed in close cooperation with the SAES and other publicly and privately supported institutions and should not intrude unduly into matters chiefly or primarily of importance to states and private institutions.

Funding for publicly supported food and agricultural research should be expanded significantly in support of the program areas of greatest need, and especially in the need areas identified in this report in light of the (a) uncertainty of adequate food and fiber supplies at reasonable prices over the long term and when viewed internationally, (b) general slippage of food and agricultural research capacity during the past decade, (c) higher constant dollar cost of researching increasingly complex problems, (d) increased responsibilities to maintain and improve the environment, (e) increased responsibility for safe and nutritionally acceptable foods, (f) persistent and formidable yield barriers in many commodities, (g) increasingly regressive forces placed on high-yielding plants and animals by the environment, insect pests, and diseases, (h) general erosion of technology reserves, and (i) the low relative level of Federal R&D investment. Appropriate rationales and justifications for a substantial increased level of funding must be provided as well as comprehensive implementation strategies each research institution and Federal agency can use in developing coordinated but individual programs and budgets. This may require the appointment of several peer panels of scientists and engineers, to assess at several levels of funding the technological feasibility and impact of selected areas of present and future research.

The role and function of USDA agencies and the SAES should be documented more clearly in those areas where funding authority and/or program responsibility overlap with those of other State, Federal, or private organizations or is presently ambiguous. Specific examples are basic research, human nutrition, research related to chemical pest control, aquaculture, and weather and climate research related to food and agriculture.

The role and function of the USDA agencies and the SAES should be examined:

A. In those areas where private industry is able and willing, either directly or with subsidized funding, to assume responsibility and can meet the needs of farmers and consumers. Examples are specific plant and/or animal breeding programs; food transport, production, and preparation; and energy substitution in agricultural uses;

B. In those areas where private industry is either reducing or relinquishing its traditional role, such as (1) proving the efficacy of specific chemicals for use on specialty crops or other limited use, (2) developing new plant varieties, animal products, and other foods or processes for enriching existing foods for greater nutritional value;

C. In those areas where USDA agencies and SAES fund or perform similar research.

While significant progress has been made in "opening-up" the present food and agricultural system, further steps are needed to insure that research policy and programs adequately reflect the needs and concerns of all groups and individuals involved and affected.

Policies should be developed to broaden scientific and institutional participation in research related to agricultural problems. Publicly and privately supported institutions not associated with the Land-Grant system, and scientists not associated with traditional agricultural disciplines, should be encouraged to devote their expertise to the resolution of food, nutrition, and agriculturally related problems and to participate in an integrated food and agricultural research system having common and documented objectives, goals, and missions.

A total coordinated program of research should be developed for the next 5 to 10 years reflecting both the special concerns which have been identified in this report and the continuing need for ongoing research not specifically addressed in this report. This program should recognize the varying roles of the USDA agencies and the SAES, the contributions which can be made by scientific disciplines and institutions outside of the traditional USDA-Land-Grant system, the role and responsibilities of other Federal and State agencies and private organizations, the availability and adequacy of facilities, and the authority and availability of funding from the various sources.

Policy should be developed and necessary legislation proposed, if needed, to permit the USDA-Land-Grant research system to make more effective contributions to meeting world food and fiber needs, particularly in the developing countries.

Continuing and intensified efforts should be made to encourage and facilitate more effective coordination of research activities between and among the State Agricultural Experiment Stations, other State and private research organizations, and the research agencies of the Federal Government, including but not limited to USDA agencies.

Continuing and intensified efforts should be made to improve the quality and relevance of agricultural research at all levels in order to make most effective use of available resources and to provide assurance and documentation of accountability.

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Issued January 1979

Chapter I - INTRODUCTION

In view of the current public concern over domestic and world food matters and the wealth of new information provided as a result of numerous studies and conferences on the subject, the Agricultural Research Policy Advisory Committee (ARPAC) and its subcommittee, the National Planning Committee (NPC), requested that this information be summarized as a part of its advisory role on agricultural research policy. This report documents principal events of the past few years; summarizes prevailing issues, concerns, and recommendations for improving the performance of the publicly supported agricultural research system; and outlines present and future roles of agricultural research in support of domestic and world food and fiber production, distribution, and consumption.

Events Leading to the World Food Crisis and Prospects for the Future

The poor crop season of 1972 that occurred in several key food producing countries and regions (India, Australia, Africa and the U.S.S.R.), along with the entry of new buyers into the world grains markets, caused a substantial shift in food prices and uncovered previously ignored areas of acute malnutrition by shifting marginally fed people from a state of malnutrition to outright starvation. In 1975, FAO estimated that some 460 million people suffered malnutrition. Causes, issues, and policy recommendations have since appeared in numerous reports, conferences, and studies at both the national and international levels in an attempt to sort out and solve the underlying problems of production, distribution, and poverty.

Several causes of the food shortfall of 1972-1973 have been cited. The following have appeared in most studies: (1) increased population growth, (2) rapid worldwide economic growth, (3) poor weather conditions in key producing areas, (4) steady increases in demand for food and feed grains in the world market, (5) increasing dependence of developing countries on food imports, (6) worldwide inflation and monetary problems, (7) the oil price jump and increased prices of various agricultural inputs (especially those associated with high-yielding varieties such as energy and fertilizer), and (8) the decisions by the planned economies to buy more commodities in the world market.

Opinions regarding the potential adequacy of long-term world food supplies run the gamut from those who believe that we simply had a bad year and no problem exists at all, to those who see impending disaster just around the corner. While these are extreme views, there is evidence that events of 1972-1975 exposed underlying uncertainties in the world food supply and the fact that even when there is no exceptional turbulence in the world market, persistent hunger and malnutrition are still quite prevalent worldwide. No extensive analysis is necessary to visualize an uneasy future. With world population expected to double in 25 to 35 years, we cannot afford to allow any slippage of production increase trends. At best, production increases should be significantly accelerated. Food production can be potentially controlled to the extent that the best available technology permits, and past

experience has shown that the development of new technology is a continuing resource which can be traced to man's instinct for survival. [4, 5, 6, 9, 17, 20, 36, 37]

One report summarizes what appears to be a consensus view on the world food situation from the standpoint of agricultural research and the experiences gained from the recent world food crisis: [9]

> During the past three or four years, modern man has been faced with unsettling new evidence that the ancient enemy, famine, remains unconquered. However, man is no longer largely helpless in the face of his own growing needs and the capriciousness of nature. The chief manageable factors to be balanced are population numbers and rising expectations on one side; and resources, technology, and policy on the other.
>
> There is reason to believe that, at least until 1985, serious worldwide food shortages can be avoided, although concerted action probably will be needed to prevent catastrophe in some of the world's more vulnerable regions.
>
> Areas of possible action include population policy; resource use and consumption patterns; research and education; political, social and economic organization, and international trade. Of these, research and education probably offer the most opportunity for immediate action. In fact, progress in all areas will depend on acquisition and use of scientific knowledge.

The assumptions underlying these prevailing views are critical. These include (1) increase in world population not to exceed 2 percent annually, (2) yearly output of crops and animals continuing upward at about the same rate as in the recent past, (3) no drastic change for the worse in world weather patterns, and (4) the assumption that food production and distributive technology will continue to improve in both developed and developing countries through research and education. [5, 9]

In spite of the outlook for global supply/demand balances for food through 1985, serious regional imbalances are likely. One important factor will be regional weather patterns. Others, more within man's control, will include (1) effects of the energy crisis, and (2) trends in worldwide food distribution, world trade patterns, and food aid programs. There is a clear possibility of malnutrition or famine in some parts of the world at the same time that excess food, or at least excess food production capacity, exists elsewhere. The FAO projections:

> ...stress the growing dilemma of grain surpluses in developed countries and rising deficits in many developing countries, particularly South and Southeast Asia. [15]

A persistent and major cause of disruptions in short-term food supplies is adverse weather. When a country such as the U.S. has cropland reserves and surplus crops in storage, and moreover is on an ascending technology curve, adverse weather at worst is an inconvenience. However, now that our cropland reserve acreage is back in production and yield curves appear to be peaking,

year-to-year weather variations will increasingly dominate supplies of major commodities. Thus, serious disruptions can be anticipated in U.S. and world food and fiber production from time to time.

Unseasonably cold weather in 1976-77, the potentially severe drought in the West, Midwest, Canada and much of Western Europe, and freeze damage to citrus, winter vegetables and coffee are examples indicating we cannot expect the favorable weather of the past few decades to continue indefinitely.

Philip H. Abelson feels that future world food crises are guaranteed: [36]

> When food is abundant, it is wasted or treated as a commodity. But when food is scarce, it is regarded as the staff of life and its distribution becomes a highly emotional issue. Food production worldwide is increasing faster than population, but distribution is uneven, reserves are limited, and bad weather conditions could lead to widespread famines. Prospects of poor crops universally are not great, but variations in harvests, good or bad, will continue to place us on an emotional roller coaster. The United States and much of the rest of the world seems to be entering a phase in which supplies of food will be adequate. However, the respite from a major crisis is likely to be short-lived. Continuing growth in world population, increasing dietary standards in the richer countries, higher costs for energy, and depleted reserves of food guarantee repeated crises...Ultimately, exponential growth of population must diminish and cease. Cessation of growth may come through calamities such as pestilence or nuclear war, it may come through starvation, or it may come through a gradual change in attitudes. If the latter road is to be followed, time is required, for customs usually evolve slowly.

T. T. Poleman feels there have been "fundamentally altered economic circumstances" which will

> ...engender major adjustments in the social and political order...For reasons Malthus could have hardly forseen:...(1798)...the misery and vice about which he brooded may yet be visited on much of the world. [36]

Major Reports Addressing Concerns About Issues and Recommended Actions

The world food crisis of 1972 elevated to new heights interest in, and concerns about, U.S. and world food production and nutrition, and the research, extension, and education supporting it. This spawned a host of conferences, special studies, and special congressional hearings, many of which are identified in the Principal Reference list in this report.

Congressional concerns about the U.S. and world food situation led to a number of special hearings and reports which addressed agricultural research, extension, and education specifically. These inquiries and studies probed into such areas as management, quality of research, gaps in programs, fragmentation, coordination, and policy. There have been several bills introduced in the 94th and 95th Congress of the U.S. directed at strengthening agricultural research. Leading scientific journals have devoted feature issues to the politics, economics, nutrition, and research implications for U.S. and

world food issues. Many of these reports reflect extensive and indepth studies of various aspects of the U.S. and world food situation.

But U.S. attention to agricultural research and world food supplies and nutrition has not been limited to the past several years. A comprehensive Long-Range Study and National Program of Research for Agriculture in the U.S. was completed in 1966. An extensive study of the world food problem was completed in 1967. In 1969, at the request of USDA, the National Academy of Sciences was asked to review agricultural research as a science and advise the Department and the Land-Grant Universities on gaps in the scientific effort and on the need for new advances. Their report was completed in 1972. [1, 2, 3]

These, and the reports cited in the references in this report, are but a few of the hundreds of reports resulting from significant planning and evaluation efforts of publicly supported agricultural research in the U.S. While much of the effort was done by scientists and administrators in agriculture, a substantial role was played by persons outside the publicly supported system including consumers, technology users, Government Accounting Office, the Congressional Research Service, Office of Technology Assessment, National Science Foundation, National Academy of Sciences, the U.S. Congress, and others.

Chapter II - THE PRESENT AGRICULTURAL RESEARCH SYSTEM

Scope and Organization

Much emphasis has been given in recent studies to the organization, coordination, performance, and scope of agricultural research in the U.S. This brief description of the present system is provided as a background for understanding suggestions for improvement in the system provided in section 4 of this report.

The publicly supported agricultural research system in the U.S. began in 1862, with the establishment of the Department of Agriculture and the Land-Grant Colleges. The prime responsibilities in this State-Federal system are shared by the 6 USDA agencies, 56 State Agricultural Experiment Stations, 19 Schools of Forestry, 16 Land-Grant Colleges of 1890, and Tuskegee Institute. This system is highly decentralized, complex in organization and program content, and responds to a wide range of problems and public interests and needs. [9, 12, 14, 17]

A unique part of the State-Federal research system described above is the system for delivering research results to users. The Cooperative Extension Service, with representatives located in each state and county, and agencies such as the Soil Conservation Service, assure that scientific results get to consumers, producers, marketing firms, and others who need it. [12]

Support for agricultural research by USDA amounted to $433 million in FY 1975, approximately 25 percent of which went to fund research in the cooperating state universities and land-grant colleges. State appropriations to these universities provided an additional $285 million. These universities and colleges also received approximately $77 million from private industry, sales, and other sources. Total funding of the USDA-SAES agricultural research programs from all these sources was $795 million in FY 1975. Approximately 54 percent of the total USDA-State research program is funded from Federal (principally USDA) sources.

Attachment I shows estimates of funding for food-related research (excluding fiber and forestry) from all major sources including private industry and Federal agencies in addition to USDA. These estimates are summarized as follows: [17]

Source	FY 1976 Funding Amount (Million $)
Private industry	393
USDA	315
Other Federal	270
State Government	230
Other	34
Total	1,242

USDA was reported as providing only 54 percent of the Federal funds and 26 percent of the total funds in FY 1976. Distribution by R&D performers showed

private industry, 31 percent; Federal Government, 29 percent; SAES universities and Colleges of 1890, 28 percent;1/ non-SAES universities, 8 percent; and other, 4 percent. [17]

The international agricultural research system includes 11 International Agricultural Institutes funded at approximately $65 million in 1976, through the Consultative Group on International Agricultural Research (CGIAR).2/ Agricultural research in developing nations is also supported by STATE/AID; FAO (funded at a reported $33 million); private foundations or institutions including Rockefeller, Ford, Kellogg, Kettering and Boyce Thompson; World Bank; USDA Special Foreign Currency, bilateral and joint commission programs, tropical and subtropical research; and through the efforts of the Organization for Economic Cooperation and Development (OECD). [9, 16, 42]

Coordination

Cooperative planning in the State-Federal agricultural research system is performed through an informal and highly interactive process involving scientists and administrators throughout the private and publicly supported system. The State Experiment Stations are oriented to solving state and local problems, are academically oriented, and are organizationally diverse. USDA agencies are more centrally directed and closer to the national policymaking process. This State-Federal agricultural research system is supported by a Current Research Information System (CRIS), which was initiated in 1965. CRIS is an automated scientific and management system which accumulates in one place essential information on all research being conducted by the organizations in the Federal-State agricultural research system. It also provides information to the Smithsonian Science Information Exchange. CRIS is operated by USDA and the State Agricultural Experiment Stations. [9, 12, 14]

Coordination within USDA agencies, State Agricultural Experiment Stations, and privately funded institutes is administered by the appropriate directors and administrators. Administrative level coordination for the total State-Federal agricultural research system is provided largely through the Agricultural Research Policy Advisory Committee (ARPAC), which was established by the Secretary of Agriculture in 1969. ARPAC is co-chaired by the Assistant Secretary of Agriculture for Conservation, Research, and Education and by the designee of the National Association of State Universities and Land-Grant Colleges. ARPAC's objectives are (1) to recommend policy with respect to planning, evaluating, coordinating, and supporting unified long-range agricultural research programs, (2) to delineate the appropriate areas of responsibility of Federal and State agencies in carrying out these programs and (3) to develop further the bases for State and Federal cooperation in planning and implementing regional and interstate research programs.

1/Thirty-one percent according to figures from ARPAC published November 1976.

2/Food Crops in the Low-Income Countries: The State of Present and Expected Agricultural Research and Technology, Rockefeller Foundation, May 1976.

Assisting ARPAC is the National Planning Committee, which is responsible for establishing guidelines for national and regional planning, reviewing plans from the regional planning units, and developing reports on national and regional research programs and program adjustments for successive 5-year intervals.

The National Planning Committee is supported by four regional planning committees consisting of both USDA and State Agricultural Experiment Station participants. A common program structure involving approximately 50 research programs is used to help focus planning and coordination activities. These regional planning committees identify regional problems and priorities and interact in their planning effort with their counterparts in other regions. Frequent meetings and workshops between action, regulatory, industry, and research organizations aid the process of coordination and planning. [9]

A significant part of the research coordination effort within the State-Federal agricultural research system is the informal but systematic interaction among scientists engaged in similar lines of work and disciplinary efforts. Duplication of research efforts are kept to a minimum through interactive participation by scientists in professional meetings, program reviews, technical workshops, task force studies, conferences, and through use of the information provided by CRIS. Publication of results in scientific and professional journals provides a built-in mechanism for coordination of efforts as well as dissemination of information. Thus, scientists have well established lines of communication with their scientific colleagues engaged in similar lines of work and maintain good liaison with representatives in private industry and in so doing stay abreast of current research efforts and plans. [12]

A schematic diagram depicting the local, regional, national, and international organizations which participate in establishing food-related research policy in the public system is shown in attachment II. [17]

Strengths of the System

Agriculture in the U.S. has provided adequate supplies of food and fiber for its own population, released vast amounts of resources to permit an unprecedented industrial expansion, and simultaneously fed large segments of a hungry world. Considered by many as a model for agricultural production for many parts of the world, it has achieved this stature largely by virtue of a research system which has provided a steady stream of new technologies. This, in turn, has been supported by an effective means for getting the technologies to users. This system has developed in response to the needs of a wide variety of crops and animals, grown on a multitude of soil types under diverse climatic conditions and affected by innumerable pests and diseases, with the point of production often thousands of miles from the ultimate consumer.

Agricultural research increases productivity by reducing costs, increasing output, reducing losses of products throughout the food and fiber chain, improving product quality, introducing new products and improved processes, and by reducing vulnerability forces which are beyond the control of producers, processors, and marketing firms. Some research projects benefit

producers and marketing firms first and then consumers as expanded output lowers prices. Some projects may benefit producers or marketing firms and consumers simultaneously, while others benefit only consumers. Technological innovation in the United States has contributed to productivity largely through labor-saving mechanical and biological improvements rather than by land-saving technology. [47]

U.S. crop productivity per acre doubled and livestock outputs increased 130 percent in the past 4-1/2 decades. One hour's farm labor now produces eight times more than in 1921. Man-hours needed to produce 100 bushels of wheat declined from 106 hours in 1914 to 6 hours today. Research and development in agriculture has contributed directly to a 50 percent increase in farm output over the last 20 years, to a 25 percent decrease in the real cost of food and fiber over the past 15 years, to large reductions in both labor and land required per unit of output, to increased incomes of commercial farmers, and to the general well-being of society.

One of the greatest benefits flowing from agricultural research has been the abundant supply of high quality food and fiber both at home and abroad at relatively low cost. No country in all of history has met the food and fiber needs of its people at the cost of such a low proportion of its total labor resources. This has been done while stabilizing erosion on millions of acres of farm and rangeland. A number of studies have been made in recent years which indicate that returns to investment in agricultural research and extension have been highly favorable, and in the order of two to three times greater than returns to other agricultural investments. Annual internal rates of returns estimates in one report ranged from 16 to 51 percent. These returns compare favorably to investments in other industries. [47]

The benefits of the USDA-State agricultural research system flow to the public through a complex interrelationship of basic, applied, and development efforts originating both within and outside agriculture. The fundamental discovery that plants reproduce in response to day length opened up new fields of applied research in agriculture, while the discoveries of several of the vitamins, of anticoagulants, and of streptomycin have benefited society generally more than agriculture. Applied research has produced a wealth of new technologies, such as sterile insect control techniques, artificial insemination methods, etc., each resulting in substantial advances in agricultural production. Development efforts, through plant and animal improvement programs, and process and product development, have led to improved frozen juice concentrates, expanded sources of penicillin, etc. Some examples of achievements by agricultural scientists are shown in attachment III.

The publicly supported agricultural research system has been under review and study on a continuing basis for the past decade. Many of these studies were done in an effort to find ways to improve the system and thus address such areas as organization, structure, coordination, review and evaluation processes, quality of work, and image. Many studies were critical of one or more aspects of the research system. Reports from such studies and hearings often include recommendations for change or improvements. The thrust of prevalent recommendations and findings will be covered in the next section of this report.

It is important to note that every report containing recommendations for change or improvement also applauds the past and present achievements in agricultural research in the U.S. Recognized strengths are (1) an integrated system of basic and applied research performance with a highly effective delivery system through extension programs, (2) a system that combines good qualities of decentralization--such as adaptive research specific to needs at locations, and centralization--such as research on highly contagious diseases like Foot and Mouth Disease in cattle, (3) productivity gains in agriculture and forestry, and (4) high returns on investments.

The following are statements in support of the present agricultural research system taken directly from several reports:

> U.S. public policy in support of research and education in the technology and organization of farming has been termed the single most effective policy element responsible for technical and economic development in agriculture during this century.1/ [9]
>
> The SAES-USDA complex constitutes our national system of institutionalized agricultural research. This complex system has functioned extremely well throughout a long period of history. Except for efforts to constantly improve efficiency and update priorities, the basic structure of this system should not be altered...The Nation's first priority in regard to agriculture is to maintain and enhance the vitality of the system. [12] - by Dr. Glenn S. Pound
>
> The Committee has looked at a number of program areas and organizational structures of agricultural research in both the U.S. Department of Agriculture (USDA) and the State Agricultural Experiment Stations (SAES). It has found many programs of excellence both in terms of scientific quality and of mission. It has found that agriculture has a large cadre of well trained, highly motivated scientists, many of whom are up-to-date and out front in their research leadership. It has found administrative philosophies and organizational structures that in general foster good research. It has found many new program thrusts and organizational changes designed to cope with new problems. [3] - from the "Pound Report"
>
> Few scientists think of agriculture as the chief, or the model science. Many, indeed, do not consider it a science at all. Yet it was the first science--the mother of sciences; it remains the science which makes human life possible; and it may well be that, before the century is over, the success or failure of Science as a whole will be judged by the success or failure of agriculture. [33] - by Andre and Jean Mayer
>
> What made the U.S. agricultural science particularly effective, however, was not only the recognized competence of its agricultural scientists to exploit the agricultural resources of U.S. soil and climate, but the administrative skill with which their findings were conveyed from the laboratory and experiment station to the working farmer. Agricultural

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1/National Science Foundation. Science, Technology and Innovation, February 1973.

Land-Grant Colleges, coupling research and education, are one form of transmission. Another was assistance of county agents. A third was a generation of innumerable reports by USDA on every imaginable phase of farm technology. [6] - by F. P. Huddle, Congressional Research Service, Library of Congress

The Subcommittees on Science, Research and Technology and on Domestic and International Scientific Planning and Analysis find that the U.S. agricultural research system has no present equal and has served the country well in helping it to meet domestic and international food needs. These successes are evidence that the system is basically sound... [17]

Innovations in Policy and Administration

Testimony by scientists, administrators, and industry representatives before Congress and reports on the results of special studies bear evidence that the publicly supported agricultural research system, while very complex, diverse, highly decentralized, and imperfect in many ways is dynamic and responsive to changing needs of society. [3, 5, 6, 9, 12, 17, 27]

Some of the most significant innovations in policy and administration decisions taken by this State-Federal research system are as follows:

- Development and full implementation of a Current Research Information System in 1965. [3, 9, 14]

- Development of an improved program structure and classification system for agricultural research including missions, goals, and research problem areas in the 1960's. [1]

- Creation of ARPAC in 1969, a Regional and National Planning System in 1971, and a National Planning Committee (NPC) in 1974, to provide a central focus and oversight for the agricultural research system. [9, 12, 14, 17]

- Request to NAS in 1969 to review the agricultural research system and to advise on gaps and new advances needed. The report was completed in 1972. The Department and ARPAC have responded with improvements to many areas in which changes were recommended. [3, 6, 17]

- A reorganization by one agency in 1972, to enhance decentralization, multidisciplinary research, and improved coordination with universities and private industry. [6, 12, 17]

- Development in 1972 within one agency in USDA of a system of periodic special onsite reviews of ongoing research utilizing peer panels.

- A generalized outward looking movement by policymakers, administrators, and scientists, including the Kansas City Conference on Research to Meet U.S. and World Food Needs in 1975, and use of peer review techniques in planning and evaluating research.

- Development in 1975-76 by one agency of a complete program planning and management system, including development of 67 National Research Programs for agricultural research. [14, 17]

- Inclusion in the President's budget for FY 1978 of a $27.6 million mission-oriented Competitive Grants Program, which would be awarded on a competitive basis to the science and technology community at large to expand basic research on problems vital to food production. Judging of scientific merit of proposals would be on the basis of reviews and evaluation by peer groups.

- Development and implementation of dual career ladder (scientist/administrator) and an executive development program within one agency in USDA.

The host of studies in recent years about the U.S. and world food situation provides very useful documentation of perceptions by a wide range of people as to the strengths and weaknesses of the agricultural R&D system and research needs. The frequency with which certain points surface provides good indicators of consensus in many instances. Too often, however, reports are but a taxonomy of researchable problems yet to be addressed adequately or solved. In many cases, most scientists and administrators have recognized these problems for years. There have been few surprises. What has been missing and what is absent in most of the recent reports is a strategy policymakers can use to followthrough with implementation: i.e., priorities, needs by problem areas, justification, and national programs.

Most reports point to the enormity of the challenge that lies ahead in food production, delivery and nutrition.

> Unless unforeseen forces cause a change in current trends, the amount of food required by the world's people within the next 20 years will more than double that currently produced--and could double again in each succeeding 25 years or less thereafter.1/

W. K. Kennedy sees four main challenges facing the world today: (1) the elimination of international conflict, (2) provision of adequate sources of energy at reasonable prices along with their efficient use, (3) stabilization of world population, and (4) provision of an adequate supply of wholesome and nutritious food with adequate protection of the environment.

Concerns about the present and future productive capacity of U.S. agriculture were reported in a study on "Agricultural Production Efficiency" by The National Research Council, NAS in 1975 [30]. "Warning signals" include depletion of land reserves and decline in rate of crop yield increases. Agriculture must learn to live with constraints necessary to a quality environment and the expectation of marked increases in costs of farm inputs. Biological limitations include genetic capabilities of plants, decline in response of plants to increased rate of fertilizer applications, leaf area index in many plants, and reproductive rates in farm animals. "Scientific frontiers" may require drastically different research approaches, such as new cell culture techniques. The agricultural R&D system since World War II has encountered an intensification in the competition for Federal R&D funds. This has been accompanied by a "decline in the relative status of agricultural workers and national priority of agriculture and agricultural research." This situation, along with complacency following several decades of abundance of agricultural products, may have been factors causing agriculture to be omitted from a list of 21 national problems designated as worthy of additional R&D efforts by the National Science Board, NSF, in 1973. [30]

1/The Role of Animals in the World Food Situation, Conference held by the Rockefeller Foundation, December 1975.

The Eighth Report of the National Science Board provides useful insight on critical problems and issues facing the total science and technology community in the U.S., based on responses to an inquiry sent to more than 900 people in universities, industry, Federal laboratories, and independent institutes. A summary of the important issues is shown in attachment IV. The similarity in these issues and those appearing in reviews, studies, and hearings on agricultural research are apparent. The following are among the more prevalent concerns reported: [39]

- Consistency and adequacy of funding, especially for basic and long-term research.

- Absence of national science and technology policy, priorities and goals; need for more coordination at national level.

- Pressure to do "targeted" research at the expense of basic research; excessive emphasis on near-term relevance.

- Excessive regulations, control, management.

- Poor public image of science and technology.

A number of studies stress the importance of agricultural research in meeting the challenge to food and agriculture.

> The most powerful single force for increasing the amount and quality of food for people everywhere is agricultural research, which is, literally, a key for progress. It is through agricultural research that scientists and technicians produce the vast body of knowledge and technology needed to increase the productivity of agriculture....Future agricultural research, adequately analyzed and pinpointed for its relevance to present and future needs, can provide one of the critical bulwarks against scarce and costly food supplies for the American people...and one of the major defenses against starvation and malnutrition in the world. The challenge is to insure that the appropriate research is stressed, and to obtain the support necessary to conduct the work. [15]

> All recent studies of the world food problem conclude that future increases in yield will contribute far more to expanded food output than increases in crop land area - except possibly for Latin America and Africa - where more undeveloped land is available. Nevertheless, as experience with the "Green Revolution" has shown, the transfer of technology to developing food production systems is a complex process with unexpected problems. [9]

Areas of high potential payoff in meeting challenges in feeding the world population include:

> ...population policy; resource use and consumption patterns; research and education; political, social and economic organization; and international trade...Research and education probably offer the most opportunity for immediate action....Progress in all areas will depend on acquisition and use of scientific knowledge. [9]

Most of the studies and reports reviewed called for greater emphasis on basic research, and most of them placed emphasis on competitive grants for funding of such research. While the reasons cited varied, the reasons given for strengthening basic research were based on one or a combination of the following: (1) limited funds for major redirections or new starts, (2) excessive emphasis on short-term results, (3) declining or exhausted reserves of new knowledge, (4) increased complexity and proliferation of problems to be solved, and (5) reluctance by decisionmakers to allocate limited funds to high risk/high potential projects. Emphasis on competitive grants was based on the desire to broaden the base of participation and enlarge the opportunities to do mission-oriented basic research in agriculture and the presumption1/ that this will increase the quality of the research effort. [1, 2, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16, 17, 28, 28a, 29, 39, 42, 43, 44]

The report most critical of the agricultural research system and one of those most often quoted in recent years is the "Pound Report" which described much of the agricultural research as "... outmoded, pedestrian, and inefficient," and went on to suggest that

> ...bold moves are called for in reshaping administrative philosophies and organizations, in establishing goals and missions, in training and management of research scientists, and in allocation of resources. The Committee found evidence that, in the allocation of resources for agricultural research, grossly inadequate support was given to the basic sciences that underpin agriculture; that the agricultural research establishment seems to have an excessive number of field laboratories with a undesirably low level of coordination and integration of SAES-USDA efforts. [3]

The Department and ARPAC responded to the charges and recommendations by the Pound Committee in 1975, and in several other instances at the request of the Congress [6, 12]. Actions taken by the Department and State Agricultural Experiment Stations to improve the publicly supported agricultural research system are also shown in an earlier section of this report.

Attachment V contains the recommendations by the Special Oversight Review of Agricultural Research and Development, which are referred to frequently in this report. [17]

Organization and Management

There has been considerable criticism of, and recommendations for improvement in, the present agricultural R&D system and its organization and management. these views can be described in terms of (1) absence of a "lead agency" role for research in support of food and agriculture, (2) fragmentation or lack of concentration of effort, and (3) a system considered by some to be too closed. Prevalent views are as follows:

1/A view not held by all scientists and administrators.

Need for "Lead Agency" Role for Research in Support of Food and Agriculture [1, 8, 12, 16, 41, 43, 43a]

> There is a broad base belief that policy should be developed in one central agency that would formulate food and fiber policy in a way that takes into account interests of all segments of the food system - the farmer, the food and fiber industry, and the consumer. It is the view of leaders in several sectors of the food system that, more than any single factor, the lack of coordinated food policy hinders productivity within the food system. [41]

G. S. Pound stated:

> Some kind of structure is needed that would bring the missions, budgets, and delivery systems of these two Federal agencies...(USDA and NSF)...as they relate to agricultural research, into juxtaposition, if not into a common framework. [12]

Several bills presented before the 95th Congress would designate USDA as a lead agency and would create supporting policy, coordinating, and advisory groups. [28, 28a, 29, 43, 43a]

Several reports recommend that the Department appoint an Assistant Secretary for "Research and Education" with research as a major mission. [1, 8, 16]

The Long-Range Study of 1966 recommended:

> The Congress should enact legislation establishing an additional Assistant Secretary position in USDA for science and education. [1]

Need for More Concentration of Research Effort [1, 6, 11, 11a, 12, 17]

The Long-Range Study of 1966 recommended "...concentration and specialization in certain locations...," noting that in the more than 100 years of agricultural research in the U.S., research has become widely dispersed because of the complexity of the problem, the diversity of personnel and facilities required, and the need to encourage the adoption of results. While many advantages exist in this type of dispersion, it was reported that there are benefits associated with grouping of specialized manpower and equipment. It was felt that it was time to examine critically programs at each location and to consider consolidation and concentration. It was noted that in 1965, 80 percent of the USDA effort was concentrated in communities served by a university. [1]

The following comments were made in connection with the Special Oversight Review:

> Support of agricultural, food, and nutrition research is fragmented among 12 or more Federal agencies. There is not a single body which provides a focal point for technical guidance, coordination and facilitation of this immensely complex endeavor. [12]

> Research that is national in scope or which requires major capital investments should be centralized when appropriate...In those cases where research might profitably be conducted in a few laboratories best equipped to carry it out, this should be done. [17]

> Is it possible that the Department, in its anxiety not to overlook any promising avenues to research, may be spreading its efforts too thinly? [6]

Need to "Open the System" [1, 17, 33]

The Long-Range Study of 1966 recommended forming

> ...program advisory committees so that they serve both state and USDA groups in advising on research program orientation. [1]

The Special Oversight Report recommended:

> Organizations outside the USDA-SAES system should be invited to participate in research and extension advisory committees.

The recommendation goes on to state:

> The involvement of individuals outside the agricultural research system will no doubt bring fresh insights into the needs of the users of the agricultural research and the consumers of its products. Where possible and appropriate, the agricultural research community might extend invitations to selected representatives of farmers organizations, and consumer groups to participate in meetings of their advisory committees. [17]

Several witnesses before the Special Oversight Review felt that the present agricultural research system is too "closed" in terms of its policymaking and priority-setting activities. Congressman Richmond stated: "...USDA does its research in a vacuum. They seldom discuss research with any other Federal agencies."

Dr. Perry Adkisson, an agricultural research scientist and administrator states:

> Too often our best agricultural scientists, who may be located in the hinterland, but who also may have the best knowledge of the real problems of agriculture, generally have little or no voice in these matters. This is true in all of the Federal agencies and institutions--USDA-NSF-EPA-HEW, and the National Academy of Sciences--that have influence on national agricultural research policies. There also appears to be little coordination among these agencies on problems of mutual concern. [12]

Andre and Jean Mayer feel the agricultural research system, however strong, suffers from a history of isolation:

> Intellectually and institutionally, agriculture has been and remains an island-a vast, wealthy, powerful island, an island empire if you will, but an island nevertheless... Agriculture also developed its own

scientific organizations; its own professional, trade, and social organizations; its own technical and popular magazines; and its own public. It even has a separate political system—executive departments at the state and federal levels, and legislative committees (in Congress, the House and Senate Agriculture Committees and a House Appropriations Subcommittee)—which operates with remarkable independence...Agriculture has been an area of particular emphasis and success for American science. Thus it has played a central role in the formation of American scientific institutions and American attitudes toward science. At the same time, in large part because of its early success and broad clientele, agriculture has become separated from the mainstream of American scientific thought.

Although the independence of agriculture has ensured the power and prosperity of its large-scale practitioners and clients, it has been tremendously costly. For lack of effective outside criticism, a great deal of agricultural research has proceeded on assumptions which are very much open to question. Thus, much of the genetic research carried out in our agricultural schools and experiment stations has been pursued without attention to nutritional values....There is no lack of nonphysicists criticizing technological developments based on physics, or of non-physicians criticizing recent trends in medical research, development, or applications, but there is a serious lack of scientific critics from outside looking at agriculture in an informed and constructive way...We need a change, both in states of mind and in institutions, if agriculture is to benefit from the intellectual evaluation it deserves and needs. If, as a result of continued insularity, agricultural, natural, and social scientists allow nutritional disaster to overtake large segments of the human race, they will deserve the criticism they receive. [33]

Coordination

The coordination of agricultural research in the U.S. and internationally received much attention in these reports. Clearly, the challenge is tremendous given the complexities of organization, objectives, programs, and legislative processes. While much has been achieved in recent years in improving coordination in the publicly supported system in the U.S., there appears to be room for improvement. This was one of the most prevalent views found in the studies and reports reviewed. [1, 3, 6, 11, 12, 15, 16, 17, 19, 28, 28a, 29, 43, 43a]

The Long-Range Study of 1966 recommended:

> A more systematic and continuing mechanism should be established to facilitate joint research program planning, evaluation, and coordination ...Major regional or national laboratories should be jointly planned by USDA-SAES Administrators. [1]

The "Pound Report" indicated that there is "an unwarranted duplication of effort in some areas and thus a wastage of resources" [3]. In response, one agency has shown that some 22 stations and lines of work were closed out during the period from 1969 to 1974. In most instances, the personnel and related resources involved were consolidated at other locations.

Department agencies report that duplication of research efforts is kept to a minimum through the holding of formal program reviews, commodity-oriented workshops, special task force studies, conferences, and by use of information from the Department's Current Research Information System (CRIS). Most scientists have established lines of communication with scientific colleagues engaged in similar work and utilize a liaison provided by representatives of industry, rural organizations, and other interested third parties who keep them abreast of current research efforts. Agencies enter into a partnership with private industry in the conduct of research through which duplication of effort is held to a minimum. [12]

The followup Work Group to the Kansas City Conference gave special attention to coordination, described existing efforts, and provided recommendations in their report: [15]

> Existing mechanisms and procedures provide a multitude of opportunities for research coordination. A great deal of coordination is achieved by way of the independent decisions of scientists and administrators following exchange of information and views. The available mechanisms and procedures should be utilized fully and extended to new areas... Seven (recommendations) are referred to existing RPC's for appropriate action; 22 are referred to other existing coordination groups; 20 propose expansion of coordination between research in the public and private sectors; and 14 new planning and coordination groups are proposed. Increased liaison with the U.S. State Department and internationally-related research is recommended as is increased liaison with pertinent Federal agencies and the private sector for agricultural research related to energy and environmental problems, among others.
>
> In addition to the foregoing recommendations, the Ad Hoc Work Group proposes additional effort toward improved decision-making procedures and toward improved mechanisms and procedures for research coordination. More specifically, the following recommendations are made:
>
> - Establish a decision-making procedure to serve all food research performers. Such a procedure should facilitate making recommendations to the Office of Management and Budget and Congress concerning funding in support of food research. This would include the selection of priority problems to be recommended for added and new funding.
>
> - Streamline and improve existing coordination mechanisms and procedures by relating them to the decision-making process.

Recommendations by the Interim Report of the World Food and Nutrition Study included:

> The U.S. (USDA and AID) should establish a specific clearinghouse and financing mechanism to facilitate individual American initiatives or responses to overseas initiatives that would link U.S. research activities with those of international R&D network [11]...That the scattered resources of relevant U.S. expertise in nutrition and related fields

> maximized by forming an association of U.S. universities and other research institutions with existing capabilities in nutritional science and appropriate related basic sciences. [11a]

One of the recommendations from the World Food Conference of 1976, held in Ames, Iowa, is as follows:

> In order to overcome constraints of personnel, equipment, foreign exchange, and information, close cooperation should be established between research and development institutions in different countries. This will help in the training of personnel, availability of equipment, and interchange of know-how in areas of pre- and post-harvest technologies to accelerate development. [19]

The report of the Special Oversight Review states, in part:

> Better interagency coordination is a desirable goal, although it may be one very difficult to achieve. New approaches to this should be tried so that ways to link other agencies with the Extension Service and the Current Research Information System may be determined...The need and desirability of maintaining a strong, pluralistic system of support for agricultural research is clear, and the opinions expressed above should not be interpreted to the contrary. The Department of Agriculture must provide guidance to, not direct, the conduct of agricultural research throughout the nation. [17]

Recommendation Number 4 of this same report states, in part:

> Improved information exchange between the public and the private sectors in the field of agricultural research should be encouraged and new ways to improve such information exchange should be explored....The Subcommittees were presented with evidence that, despite the close ties between the USDA and agricultural industries, there is a need for improved coordination and communication among the public and private research efforts. [17]

Recommendation Number 13 states, in part:

> Interdisciplinary efforts, especially among scientists and basic researchers outside the agricultural research system, should be encouraged...Efforts to bring together scientists from within and outside the agricultural research system and from a variety of disciplines related to agriculture should be encouraged and supported through the policies of the Federal agencies which fund agricultural research. [17]

Federally supported research on related problems is coordinated among agencies and departments very informally and largely on an ad hoc basis. There are no well established formal program structures or administrative procedures to enhance interdepartmental coordination. NSF's efforts to collect and classify data on research expenditures, as well as the topical conferences which they sponsor provide a link in overall coordination of Federal research. Most other efforts revolve around specific topics and persons; are put together

on an ad hoc basis; and include those agencies or individuals who are sufficiently interested in the topic to initiate their agency's involvement. As a result, agricultural R&D related reports, plans, and budget requests from one department rarely reflect the activities and plans of other departments, even on related goals and programs. Examples include USDA and NIH on human nutrition research, and USDA and AID on international agricultural research. Efforts are being made to improve interdepartmental coordination, such as the establishment, under Title XII of the Federal Assistance Act, of a Board for International Food and Agricultural Development.

Increased cooperation and coordination with other developed nations in public agricultural research, especially that oriented to the needs of developing nations, is needed. The current cooperation of USDA with the OECD agricultural research administrators is an example of the activity anticipated. [16]

Judged by the number of "sunset," zero-base budgeting, and bills to "strengthen" agricultural research, Congressional actions propose steps intended to improve coordination of publicly supported agricultural R&D. These are in the form of either periodic reviews by Congress or by forming interdepartmental planning, coordinating, and review mechanisms such as policy, operations, and advisory groups. [28, 28a, 29, 43, 43a]

<u>Review, Evaluation, and Justification of Ongoing Programs</u>

Numerous "Sunset" bills have appeared before the 94th and 95th Congress in which either zero-base budgeting or stringent periodic reviews of all federally funded programs were recommended. Most of these bills were intended to "eliminate inactive and overlapping Federal programs" and to require "authorizations of new budget authority" for Government programs every 2 to 5 years.

Additionally, Senator Muskie of the Subcommittee on Intergovernmental Relations of the Committee on Government Operations held Hearings on the Government Economy and Spending Reform Act of 1976 during March and April of 1976. The thrust of these Hearings concerned the systematic review and examination of base programs by the Congress including zero-base budgeting concepts. The implications of all of this are that agencies may be required to present, on a systematic basis, <u>all</u> programs to appropriate Congressional Committees at 4-to 5-year intervals, not simply justifications of proposed increases.

Virtually everyone who appeared before this Committee generally endorsed the concept of zero-base budgeting. This seemed to reflect a concern on the part of all parties to respond to public reaction over proliferation in programs in the Federal establishment, which now reportedly number well over 1,000.

In Senator Muskie's Hearings, it was pointed out that a great danger in implementing a zero-base program in the Federal Government is the possibility of totally overloading those involved in the process with a volume of information that cannot be processed and utilized as intended. This happened in PPBS and it happened with the Department about 15 years ago in a zero-base budgeting and review activity. Many of those in research feel that the key

to effective execution of zero-based budgeting is to concentrate on program aggregations that are coherent, relatively large, readily understood, and to present and evaluate these at relatively long intervals such as each 5 years. Ideally, from an agency's point of view, a cyclic process would be preferable with several programs being evaluated one year, several others the following year, etc.

A number of reports recommend more extensive use of peer review and evaluation techniques to provide decisionmakers with the input of highly qualified scientists in assessing projects and programs. This is a direction in which agencies and state institutions are moving. [3, 6, 12]

Examples of views and recommendations concerning reviews, evaluation, and justification of research programs are as follows:

> ...that concerned agencies and organizations mount an effort to appraise research contributions from the social sciences appropriate to the solution of problems involving food production. [8]
>
> Orderly and periodic means for jointly reviewing research plans, budget requests, and programs at the State level should be established by Directors of SAES and Area Directors for the ARS and the ERS. [8]
>
> Each agricultural research unit should assure adequate systems and criteria for the critical review and evaluation of research. Some government research agencies, many SAES, and other agricultural research organizations have well designed systems for the planning, review, and critical evaluation of research. However, in too many instances these functions are carried out ineffectively. Strong encouragement should be given for strengthening these aspects of research operations. [8]
>
> "Special reviews" and "on-site reviews" of State Agricultural Experiment Stations, currently performed by the Cooperative Research Service, should be strengthened and more widely used...There should be an ongoing evaluation of the scientific bases which govern food and agriculture regulations ....Witnesses were generally in favor of more extensive use of "scientific peers" in the review of research projects and programs. [17]
>
> Establishing within the Food and Nutrition Council, OSTP, and USDA improved mechanisms for efficient and continuous evaluation of research priorities and performance with a basis for establishing responsibility for seeing that research is carried out. Such review is crucial to improving and maintaining the quality of food and nutrition research consistent with current priorities. [16]

Food and Fiber Policy

One of the most prevalent themes running through the reports reviewed is concern over what is viewed as a lack of, or inadequate, policy on research in support of domestic and world food and fiber supply and demand, especially on a long-term basis. [3, 6, 8, 9, 12, 16, 17, 21, 28, 28a, 33, 38, 41, 43, 46]

In defense of food and agricultural policy, Secretary Butz has described U.S. policy as "abundance," or "freedom from government restraints for farmers." In a symposium in 1976, he concluded: [46]

> We must have a food policy designed to assure that 213 million Americans are well fed at reasonable prices. Such a policy must strive to provide food to assist in feeding literally hundreds of millions of people around the world - both cash customers and the needy. It must continue American farm exports as the number one source of foreign exchange, and to help pay for the large variety of goods and services we have opted to import from abroad - including vitally needed minerals and petroleum. It must make sure that food will always be available to help bring a peaceful and prosperous world.
>
> All of these things add up to a positive food policy. I am confident that the steps taken in recent years toward a food policy, to achieve those objectives which I have briefly discussed here, are being made in ways fully sensitive to market forces--so that the emerging new food policy will be flexible, workable, and successful for decades to come.

The Department and ARPAC point out that agricultural research involves a broad spectrum of scientific disciplines and subject matter areas. Authorization of these programs at the Federal level derives from numerous Congressional acts which, when taken collectively, establish an overall national policy for the conduct of research in food and agriculture. In general, they feel present policy, while broad, provides a sound framework within which timely policy decisions can adapt. One approach whereby policy development might be improved is offered:

> A possible approach to defining current agricultural research policy would be for the Secretary of Agriculture, the President of the National Association of State Universities and Land-Grant Colleges, and the Head of the Office of Science and Technology Policy to jointly develop a set of proposed national agricultural research goals and objectives for consideration for endorsement by a resolution of the Congress. This could be updated at intervals as needed.1/ [12]

The report of the Kansas City Conference presents a background for public food policy. It states in part: [9]

> Public agricultural policy in the United States has historically been concerned with (a) maintaining reasonable and stable farm incomes; (b) increasing efficiency through research and education; and (c) coping with the increasing agricultural output of a highly productive food and fiber sector.
>
> Most public policies in agriculture in the past have been designed to support farm income or to increase farm output. However, in recent years policies that affect agriculture have been adopted to protect other

---

1/Response to Congressmen Symington and Thornton by O. G. Bentley and R. W. Long, September 9, 1976.

interests, e.g., health, soil conservation, food quality. Concern for a clean and unpolluted environment has led Congress and various agencies and departments to more closely examine the issues and to look for ways of increasing food production while accomplishing environmental goals as well.

U.S. international food policies have been carried out largely as part of our foreign aid programs. There are two major programs: food assistance under PL 480 and agricultural development assistance carried out by the Agency for International Development.

Among the numerous questions and issues relative to improved policy formulation, management structure, and coordination of research which were discussed are:

- What are the national and international structures within which agricultural research and development are being conducted? [17]

- Is a comprehensive formulation of a "national (or international) agricultural research policy" necessary, desirable, and/or possible? [17]

- Are the goals of agricultural research sufficiently defined to determine priorities throughout the system? [17]

- Are the resources available for agricultural research sufficient, and are they being efficiently utilized? [17]

- What is the role and importance of the private sector in agricultural research; and is this research complementary to or competitive with public sector research? [17]

- What should be the elements of a long-term agricultural research and technology plan for both domestic and international purposes?

- Given the set of constraints which society is placing and is likely to continue to place upon agricultural production, and assuming American agriculture probably will have to live with these constraints, what direction should agricultural science and technology in the U.S. take to maintain productivity growth in U.S. agriculture consistent with societal objectives? [6]

- USDA research on ways to increase the prosperity of domestic agriculture runs counter to the broader goal of extending U.S. technical skills in agriculture to developing countries. The support of farm policies and farm surpluses by export runs counter to the general objective of assuring the U.S. consumer adequate nutrition at lower prices. How do we resolve these contradictions? [6]

- Should the laboratory be constrained in its quest for new knowledge and new products; or does the farmer have an inherent right to be protected

from the competition of synthetic substitutes? When the interests of the consumer conflict with those of the producer, how is the issue to be resolved? [6]

- A national strategy should be encouraged for U.S. involvement in technical collaboration in agriculturally developed nations. [8]

- What trade-offs is this country willing to make between agricultural production, energy consumption, materials availability, land use, and environmental quality; between agricultural production, the survival of the independent family farm, and the preservation of rural life as it now exists; between agricultural production, improved nutrition and food safety? Within this framework, how can agricultural research best be conducted? [17]

Many views, recommendatons, and concerns have been directed at U.S. and world food and agriculture policy. The following are representative of those reviewed in this study:

> It seems fair to say that at present the U.S. does not have a food policy. The elements of what would be a food policy are spread throughout the government structure without any structural focal point....There is a broad base belief that policy should be developed in one central agency that would formulate food and fiber policy in a way that takes into account interests of all segments of the food system - the farmer, the food and fiber industry, and the consumer. It is the view of leaders in several sectors of the food system that, more than any single factor, the lack of coordinated food policy hinders productivity within the food system. [41]

Recommendation Number 1 in the Report of the Special Oversight Hearings, states that "a clearly defined national policy for agricultural research should be established." [17]

Recommendation Number 2 states that:

> Individuals qualified as knowledgeable in the agricultural sciences should be included at the highest levels of national science policymaking.

The recommendation goes on to state:

> The present isolation of agricultural science from the policymaking process for the rest of the sciences should be changed. The principles embodied in our national science and technology policy cannot be adhered to nor effectively implemented under these circumstances, and this situation is detrimental to the country as a whole. Agricultural science must be treated as an equal partner with the other sciences in the determination of priorities among the sciences and in the formal issue of policies affecting the conduct of research and development. [17]

One study recommended establishment of a food and nutrition council to deal with domestic and international food issues. It would be located in the Executive Office of the President with close links to OSTP [16]. Senator

Talmadge introduced in the 95th Congress on January 18, 1977, "The Food and Agriculture Act of 1977" - S. 272. The following information is taken from the Congressional Record - Senate dated January 18, 1977:

> The need for a sound agricultural policy is probably greater today than ever. The demands placed on our farm production capacity in the last few years are unprecedented. And at the same time, production and marketing costs have risen drastically. American agriculture, more than ever, has become a matter of national and international concern. As a nation, we cannot take the chance that there will be enough production to fulfill market demands. We must use our policymaking powers to assure that this is accomplished. [43]

Questions about adequacy of science and technology policy have not been limited to food and agriculture by any means. The following statements are taken from an article by Vernon Pizer, "Who Unplugged America's Science Machine?", Bioscience, May 1974:

> Those who pursue science all agree that the primary flaw in the way the Nation handles science is a failure to devise a rational, consistent policy. As Handler says, "This country has never had a science policy. We never looked at the subject in its entirety and formulated an intelligent, overall approach. What we have had is bits and pieces of ad hoc policies to deal with bits and pieces of science...

Abelson summarizes in the same article:

> ...every time a field of science generates a wave of popular enthusiasm every Government agency tries to get on the gravy train: as soon as popular enthusiasm switches to something else they immediately change trains. What we need desperately is a sound, coherent government way of handling science, one that cuts out the train changing.
>
> What we seem to have is a science/technology community afloat on a sea of governmental ineptitude, erratically propelled by winds that blow hot or cold or not at all from the White House and the Hill.
>
> But most of all the Federal Government must for the first time in history frame an overall policy that eliminates crash-basis science, erratic funding, and submission to faddish enthusiasms, and that substitutes consistency, continuity, balance between research and application, and long-range planning relating science/technology to national needs and goals.

The World Food and Nutrition Study recommended:

> There is a need for an annually updated statement of research policy which in effect would constitute a national strategy for the U.S. agricultural research system. This statement--requiring input from biological, physical, and social scientists--should reflect the main thrusts of U.S. social and economic policies and indicate the impact of these on the agricultural research system as guidelines for designing research programs. These guidelines would reflect the realization of what can

be accomplished with the resources available to the system, including reallocation of present resources, and provide guidance to those who are responsible for committing resources to it. [8]

Immediate steps should be taken to establish an organization for funding and coordinating activities of State, Federal, and private institutions in the planning and management of technology innovation programs. Long-range support for U.S. institutions involved in international technology innovation management programs should be provided. [8]

Recommendation from the Interim Report of the World Food and Nutrition Study:

...that dispersed nutritional activities within the Federal Government be brought to a focus and given coherence by the creation of a high-level food and nutrition policy board or council, or comparable mechanism. [11a]

Another study recommends:

As a top priority that there be established under the Office of Science and Technology Policy in the Executive Office of the President, an Advisory Office for Policy Issues Related to the Use of Renewable Material. [21]

One World Food and Nutrition Study team recommends: [16]

Establishing an improved--but not inflexible--division of labor among research funders such as NSF, USDA, and AID. Such a division of labor should recognize that the basic charge of NSF involves basic disciplinary research related to maintaining the health of the sciences. On the other hand, USDA, AID, and NIH research has a primary mission-oriented thrust which includes basic and intermediate research components. The leadership for providing such a division would come from the Food and Nutrition Council.

The problem of satisfying world food needs begins with the development of a central focus in the Federal Government for the development of policies, strategies, and programs to deal with the domestic and international food and nutrition issues. USDA's role in the establishment of food and nutrition strategy, policies and programs could be improved by strengthening its policy assessment and analysis staff.

Policy decisions that have major impacts on the U.S. and the world will necessarily continue to be made in many agencies, including USDA, NSF, HEW, State Department, Treasury Department, Commerce Department, CEA, OSTP, ERDA, Defense Department, Transportation Department, Labor Department, and agencies of the Executive Office of the President. There will be a continuing need for coherent rationalization of these forces, decision points, and policies within a consistent U.S. food and nutrition strategy that comprehends the U.S. and world food situation and anticipates future needs. It is recommended that a Food and Nutrition Council be established in the Executive Office of the President. Such a Food and Nutrition Council would have three primary functions:

a. Provide continuous assessment and analysis of the world food situation, problems, and policies.

b. Establish policy objectives and goals.

c. Design, evaluate, and rationalize the mix of policies and programs to reach established goals and objectives.

The Baker-Ramo Committee recommended that:

> Research in fields dealing with food science--specifically nutrition and food distribution--should receive early attention from OSTP. It is recommended that the OSTP examine carefully the results of the current NAS World Food and Nutrition Study and assure that the institutional and funding arrangements are adequate to implement the NAS Study recommendations, including those dealing with international aspects of the problem. [44]

The Department, in responding to OSTP on December 15, agreed that research on nutrition and food distribution should receive early attention by OSTP and stated:

> With the acceptance of the "lead agency" designation of the Department of Agriculture for the food and nutrition problem area, this Department would work closely with OSTP and other appropriate units of the Executive Branch and the Congress to develop a national food and nutrition policy to insure implementation of the concepts set forth in this paper.

Senator Humphrey, in a symposium in 1976, described the food and agriculture policy issue as follows: [46]

> The major question is whether the nation should pay a continuously rising level of food prices that may be necessary to bring forth a growing food supply under conditions of great price uncertainty, or whether it would rather use some new government policies and programs to reduce farm price uncertainty and hence the average level of prices necessary to give producers an incentive toward larger production.
>
> The answer to that question depends on whether the present price uncertainty is inherently a part of a market-oriented agricultural economy as now exists, or whether it is an outgrowth of the unusual events of the past three years. Or, stated differently, is the instability of the type experienced in the last three years inherent in a free market agricultural economy?

W. V. Barton, noted that "Consumers also discovered the Department of Agriculture during the period since 1972" and suggested approaches in formulating food and agriculture policy: [46]

> Reorient the Department of Agriculture to render it responsive, in a systematic and balanced way, to the legitimate demands not only of the commercial agricultural establishment, as described earlier, but also of consumer interests.

> Embrace with renewed zeal the traditional clients of the Agriculture Department, and adopt the explicit stance that Agriculture's role should be to press to the maximum the food producer's and food industry's perspective against competing power centers that share jurisdiction over agricultural policy and that may reflect other interests and perspectives.

D. F. Hadwiger reported several alternative futures for USDA policy on food and agriculture: [46]

> One is gradual dismemberment, to which the Department is vulnerable in the absence of any desire for renewal on the part of its Secretaries or its more permanent leadership.
>
> Another is a retreat to the "old department," perhaps without the excellence and vitality that characterized the Department in its earlier years.
>
> The Department might maintain its present political, organizational posture, despite considerable shifts in agency workloads and budgets.
>
> The USDA might seek renewal, by means of a more intensive commitment to its traditional missions and its new agenda.

Attitudes about public food and agricultural policy are changing. In an address given at the 1976 American Agricultural Economics Association, K. R. Farrell stated: [49]

> The most basic feature of current policy setting is agriculture's growing social, economic, and political interdependence...U.S. agriculture and its role in world affairs has been transformed radically and irreversibly. The upshot of these circumstances, rooted deeply in the processes of economic development, changes in human aspirations and social goals, and new political realities, is to make it increasingly difficult - if not impossible - to analyze and understand agriculture and related public policies except as an integral part of national and world economic, social, and political systems.

At this same meeting, G. E. Schuh described a number of major implications of changes in the economic environment of U.S. agriculture:

> (a)...an almost total disappearance of the excess capacity that existed at prevailing price ratios for such a long period of time ...(b) the management of agricultural policy will be more complex ...(c) the price of food to the U.S. consumer will be determined in part in international markets...(d) U.S. consumers now have an interest in improving world agricultures and in bringing world population growth into balance with potential food supplies...(e) domestic agricultural research policy needs to be revamped...the balance between basic and applied research (greater emphasis on basic research)...new means of financing agricultural research need to be devised (i.e., check-offs, land tax, export tax, etc.).

A recent report on food and agricultural policy options by the Congressional Budget Office reflects no fundamental change in the position of U.S. agriculture from the 1950's and 1960's. The authors conclude: [50]

> It continues to have the capacity to produce more than domestic and foreign markets will accommodate at acceptable prices, when worldwide growing conditions are favorable. Thus, the threat of surplus stocks, depressed farm prices, and higher program costs remains real.
>
> The farm community, with the most direct stake in the outcome of legislative actions, clearly sees the threat of falling farm prices and eroding incomes as the key issue...Consumers, on the other hand, worry more about high retail food prices and how farm policy can be used to avoid a repeat of the rapid food price inflation of 1973-1975...
>
> Four issues seem to be at the center of debate about new farm legislation. They are:
>
> - At what levels and through which mechanisms should prices be supported?
> - Should this support include protection against natural hazards?
> - Should consumers be protected from the effects of very high farm prices as producers are now protected from very low prices?
> - How open should U.S. agricultural markets be to other nations?

Legislation

The U.S. Congress has been highly participative in the debate over food and agriculture issues in recent years. A comprehensive Special Oversight Review of agricultural research and development was held in 1975-76. Studies have been conducted at their request and reports submitted by OTA, GAO, and the Library of Congress. In 1976, extensive Hearings on the Government Economy and Spending Reform Act of 1976 were held by the Committee on Government Operations. These Hearings covered food and agriculture as well as other Federal programs. Studies have been made by the Survey and Investigation Staff of the House Appropriations Committee. Numerous "Sunset" and agricultural research bills have been presented. Most of these Hearings, studies, and bills have been covered in other sections of this report. [6, 7, 12, 14, 17, 27, 28, 28a, 29, 38, 43, 43a]

Concern by Congress is reflected in a report by Vernon Pizer based on a comment by a member of the House Committee on Science and Astronautics:

> When the Administration comes up with a program, they send it to us for legislative action but they don't accompany it with the high-level discussion out of which the proposed program emerged. This denies us access to the reasoning behind it and to evaluation of the options and alternatives that were considered. It leaves us more or less groping our way until we finally reach the hearing stage and try to ask the right questions to witnesses. But in the meantime, a lot of members have gotten themselves

> locked in by their public statements on the proposals, especially if it is one that attracts wide attention. That is a very unhealthy situation.1/

House Bill 11743, "An Act to Establish a National Agricultural Research Policy Board," better known as the "Wampler Bill," was overwhelmingly approved by the House of Representatives in July 1976. The bill was resubmitted in January 1977 as the "National Agricultural Policy Act of 1977." Its purpose is to strengthen agricultural research, expand funding, provide an Assistant Secretary for Research and Education in USDA to coordinate all federally related research, create a 23-member advisory board to the Secretary of Agriculture, and establish a competitive Federal grants program in the Department. Additional bills designed to strengthen agricultural research have been submitted to the 95th Congress, including S. 248, S. 272, S. 275, H.R. 78, H.R. 79, H.R. 2223, H.R. 4394, and H.R. 4863.

Senate bill 275, "The Food and Agricultural Act of 1977," submitted to the Congress by Senator Talmadge on January 18, 1977, is intended to greatly strengthen publicly supported agricultural research in the U.S. The Congressional Record--Senate dated January 18, 1977, states:

> To assure more reasonable funding, the bill specified that food and agricultural research funding should equal at least one-half of 1 percent of domestic expenditures for food plus (one-half of 1 percent of) gross agriculture exports. To fill the gaps, the bill reiterates the need for human nutrition research and provides new initiatives for basic research, aquaculture, and animal health. To assure continuity, the bill strengthens the vital partnership between the states and the Federal Government that is represented by the State Agricultural Experiment Stations, the Cooperative Extension Service, and the Land-Grant Colleges. Finally, to assure better coordination and a more cost-effective research program, the bill designates USDA as a lead agency and creates coordination and advisory panels, which will assure that Congress and the President know the needs of the people and the problems and priorities of our researchers, and that all segments are coordinated. This is the underlying foundation of our proposal for agricultural research, but the ultimate objective is the welfare of the American people. [43]

In presenting S. 275, Mr. Talmadge stated:

> The need for a sound agricultural policy is probably greater today than ever. The demands placed on our farm production capacity in the last few years are unprecedented. And at the same time, production and marketing costs have risen drastically. American agriculture, more than ever, has become a matter of national and international concern. As a Nation, we cannot take the chance that there will be enough production to fulfill market demands. We must use our policymaking powers to assure that this is accomplished...The statement speaks to the failure of the Congress in the past to expand agricultural research support in spite of the turnaround from agricultural surpluses to worldwide shortages. [43]

1/"Who Unplugged America's Science Machine?," Bioscience, May 1974.

Senate Bill 248, submitted by Mr. Dole before the 95th Congress in January 1977, calls for establishment of "a National Agricultural Research Policy Advisory Board, and for other purposes." It was referred to as the "National Agricultural Research Policy Act of 1977." The bill speaks to (1) new demand on food production on a worldwide basis, (2) need to increase funding for agricultural research with emphasis on inflationary costs over the past 10 years, (3) fragmentation of research, noting that several agencies or departments other than USDA are increasingly involved, (4) establishment of a national agricultural research policy advisory board, (5) provisions for competitive grants programs, (6) provisions for coordination of human nutrition research, (7) provisions for grants for mission-oriented research, and (8) authorization for appropriations. [28a]

World Food and Nutrition Study teams of NAS envision the need for legislative changes in these words:

> This mobilization of U.S. potential requires, among other actions, explicit legislative mandates to, and adequate funding of appropriate departments of the U.S. Government--including USDA, AID, NSF, HEW, and perhaps others.
>
> At present, with one exception, USDA agencies are administratively restrained from using regular USDA appropriations for international research unless a substantial and clear benefit to the U.S. can be shown. State recipients of USDA funds are limited by the phrasing of the Hatch Act. Elimination of these constraints could be a large initial step ahead in facilitating international research. [16]

<u>Operational Constraints</u>

Two operational constraints in the publicly supported system are worthy of note, inadequate research facilities and employment ceilings.

<u>USDA-SAES Facilities</u>:

Recommendations from the Report of the Ad Hoc Work Group on Most Important Problems include the following: [15]

> An appraisal of agricultural research facilities was reported in 1973 by the Agricultural Research Facilities Review Task Force. This group found that all SAES had space inadequacies both in laboratory and office facilities. Similar space problems were expected in the Land-Grant Colleges of 1890 as they hired staff to meet the requirements of their already expanded program funding. At that time, ARS had a surplus of research space but a need for modernization. This surplus has been markedly reduced in the past few years.
>
> Special appropriations and enabling legislation, if necessary, should be provided to correct the inadequacies of agricultural research facilities. This need is particularly critical for the State Agricultural Experiment Stations (SAES) and the Land-Grant Colleges of 1890. First priority should be given to modernization and renovation for both the universities and USDA.

Needs vary widely between locations, ranging from research-support structures such as greenhouses, environmental chambers, and insectaries not designed to provide either office or laboratory space for scientists, to sophisticated and unique laboratory facilities designed for specific types of research. Research facilities frequently are not freely interchangeable between different scientific disciplines, and major renovation may be necessary to adapt existing laboratories to new uses. Changing technology also renders existing laboratories obsolete with consequent requirement for updating and renovation.

Employment Ceilings:

Employment ceilings, as a mechanism to control Federal civilian employment, is a significant management constraint for departmental agencies, and has become an integral part of agencies' planning and management processes. Although personnel ceilings have not prevented fulfilling program responsibilities, they have created occasional difficulties in planning and staffing essential research programs. In recent years, employment ceilings rarely are consistent with the funds and responsibilities authorized. Various methods are used to cope with restrictive employment ceilings including (1) the transfer of personnel from location closeouts and reduced or terminated programs, (2) general strengthening of current programs in high priority areas through purchase of supplies and equipment, (3) increase in extramural activities to complement in-house research needs, and (4) reductions in administrative management areas to provide additional personnel slots for program requirements.

Quality of Research

Concern about the "quality of agricultural research" has been noted in a number of reports [3, 7, 12, 17]. This concern is both difficult to describe explicitly and to differentiate clearly from other issues, such as concerns about organization and management, leadership roles, image, and the need for a competitive grants program. Also, it is difficult to discern if concerns about quality of research are persisting as a continuing issue or stem from the emphasis given to the subject in the "Pound Report," which states that "...much of agricultural research is outmoded, pedestrian, and inefficient." [3]

Indications that quality of agricultural research is still an issue is evident in two reports, one of which (Special Oversight Hearings) states as follows: [17]

> ...after a period of three or four years, this same criticism of the present agricultural research system is evident in much of the testimony presented to the Subcommittee. Measuring the quality of research is a difficult, sometimes impossible, undertaking. This is especially true when the research covers a broad range from the very basic to the most applied such as in the case of agriculture. In carrying out its responsibility for examining the state of science and technology over the years, the Committee on Science and Technology has accumulated knowledge of and, it believes, some insight into problems of this type. Relying on this

experience, it is believed that a strengthening of certain elements of the existing agricultural research system will provide increases in the quality of the system's output.

The same report considered the following aspects as being particularly important: [17]

- Competitive procedures for the award of agricultural research grants should be more widely employed

- "Special reviews" and "on-site reviews" of State Agricultural Experiment Stations currently performed by CSRS should be strengthened and more widely used

- Research that is national in scope or which requires major capital investments should be centralized, when possible

- Excellence among members of the agricultural research community should be given recognition.

Image

Concerns about the image of the publicly supported agricultural research, its results, and its scientists appear to be of three types: (1) decline in confidence by society in established institutions, and especially technology, (2) level of esteem in which agricultural research and its scientists and administrators are held by other scientists, and 3) a continued reduction in the political base support for agricultural programs. Several reports address some aspects of this issue. [6, 12, 17, 33]

Lack of public support for and even antipathy toward agricultural research developed during the years of crop surpluses. This disenchantment was enhanced and compounded by failure of concessional sales and surplus food contributions to lead to permanent solutions to either U.S., or developing country food production and distribution problems; and by environmental, social, and political concerns about the direction and effectiveness of agricultural research programs. Much of the recent criticism probably stems from the aggregated effects of "Silent Spring" in 1962, "Hard Tomatoes Hard Times" in 1972, the "Pound Report" in 1972, and the followup articles in the press and scientific journals, which express commonly held views that the publicly supported system is planned and managed to serve the interests of "agribusiness" and other "special interest groups."

What appears to have been a decline in the image of the entire science and technology community by the public is also a contributing factor. The accelerated attention given to food and agriculture in the past several years had the effect of focusing public concerns with a larger issue (science and technology) on food and agricultural research.

J. J. McKetta feels that the public is not getting all of the necessary facts, stating:

I agree, as Thomas Jefferson did, that if the public is properly informed, the people will make wise decisions. The public has not been getting all of the facts on matters relating to ecology...Let's not cry "wolf" until we are reasonably certain that we have done enough homework to know what a wolf looks like. Otherwise, we may undermine our credibility and not be believed by the people when we warn them of the real wolves that do exist.1/

R. S. Morison describes how the research and development role of agencies can be so easily forgotten or ignored:

Even the Department of Agriculture, representing a field in which spectacular technological changes have been made in this century, is identified in the public mind with price supports, low interest rates, and the survival of populism, rather than the home of scientists like Sterling Hendricks or E. F. Knipling.2/

Several reports contain information suggesting that the Federal Government and the science and technology community at large give agricultural research and its scientists second class status in the research community.

Wittwer states:

The...(NSF)...was created and is currently sponsored by Congress, and reports directly to the President. Among the 21 options, or national problems, warranting greater research and development efforts according to (their) report—Science Indicators, 1972, the 1973 National Science Board's report, food production is not on the list. There is also a complete absence of people even remotely connected with biology—let alone agriculture--in this top echelon of the National Science Foundation. [17]

Recommendation Number 8 in the report of the Special Oversight Hearings states that:

...excellence among members of the agricultural research community should be given recognition...The hearings clearly suggested that the esteem in which the agricultural scientist is held by other scientists and society is not as high as it should be, either here or abroad. This may be in part due to the average or perceived quality of the research, to the "mundane" or "earthly" nature of the research, or to the fact that much of the research is applied rather than basic. Whatever the cause, it is imperative that the success of agricultural research and the accomplishments of the individual researchers be made known to the broader scientific community and to the public. [17]

1/"Has the World Gone to Hell," American Motorist, June 1975.

2/Chapter by R. S. Morison, Problems of Science, Goals and Priorities in book Science and the Evaluation of Public Policy, edited by J. A. Shannon, the Rockefeller University Press, New York, 1973.

The Mayers described agricultural research as a self-imposed "Island Empire" [33]. If so, and if the nonagricultural research community holds agriculture in such low esteem, the nonagricultural research community is not without fault.

A cautionary note about image may be useful. Overemphasis on attempts to improve image could lead to preoccupation with cosmetic factors and processes at the expense of more fundamental issues.

Concerns About the Environment, Health and Safety, Natural Resources, Consumer Interests, Redirections

Many constraints or general "discontinuities" affecting agriculture have been presented. These emphasize the highly dynamic situation which agricultural policy and programs face. Discontinuities presented include: (1) A flattening of the rate of increase in per-acre yield of U.S. agriculture, (2) an absence of visible means of increasing per-acre yields in the U.S. agriculture by more intensive application of known technology, (3) an apparent slowing of the rate of population shift from farm to cities, (4) large population increases in countries least efficient in agriculture and the prospect of increased reliance on the U.S. to alleviate future famine conditions, (5) increased need for soil and water conservation and insistence on environmental quality standards, (6) increased need for U.S. exports to balance rising costs for imported fuel and materials, (7) increased costs of inputs for agricultural production, processing and marketing; including fuel, fertilizer, and agricultural equipment and supplies, and (8) depletion of cropland reserves. [16]

Most, if not all, of these discontinuities appear to suggest the need for radical improvement in U.S. agricultural productivity per acre, the need for increased processing and marketing efficiency, and an ability to support a larger rather than smaller farm population. One report notes that studies by USDA and NAS hold out little hope for such radical improvement in the absence of new scientific breakthroughs. Accordingly, the report indicates, one can choose between the alternatives of (1) making the best use of present systems of food and agriculture with slow incremental improvement in farm technology, or (2) coupling this approach with some additional (or diverted) funding for basic agricultural and related scientific research. Domestic agriculture may have peaked out, and no longer be capable of further dramatic increases. [6]

Testimony before the Special Oversight Hearings which addressed concerns about new challenges facing public and private agricultural R&D includes the following:

A. Clausi, General Foods Corporation, noted that respondents to a survey on future allocation of R&D dollars in the food industry observed:

> At the top of everybody's list was a considerable increase in the dollars allocated for testing safety and toxicology, as well as for quality control and quality assurance. Product and process development, new or established, as well as basic sciences were much further down the list when it came to increase in funding. [12]

Another question asked in that survey was:

> What single problem will present the greatest challenge to food industry companies between 1975 and 1985? The answer given most often was constraints resulting from government regulations. Next most frequently given answer was raw material costs or charges and their consequent impact on food prices, but this was a very distant second. [12]

Clausi testified that this change in priorities for private industry research efforts could have detrimental effects on future progress to meet world food needs. He said that private industry representatives, in their response to the questions in this survey:

> ...indicated strongly that they are pessimistic about new developments forthcoming in food processing; that progress in the food industry's search for new ways to provide consumers with nutritious, adequate, and interesting foods is being slowed down significantly by the maze of regulations that must be followed--especially those which mean excess testing for safety and additional quality checks over those already in effect. This obvious preoccupation with safety, toxicology, and quality controls on the part of the food processing research community translates into less time and fewer dollars spent on basic research and new product development. Consequently, it also can mean that a gradual slowdown in the rate of technological progress in the food industry may well result. [12]

William Hollis of the National Agricultural Chemical Association noted that areas of environmental, food safety, and other research not directed toward increased production or new food products or processes provide:

> An added dimension which is getting emphasis and deserves the emphasis... We are having to divert from static, committed funds into these ancillary areas. All that we are saying is that these requirements are imposing new and sometimes inadequately conceived constraints on the existing agricultural research and production systems. [12]

Consumer pressures for "natural" or environmentally safe foods were also stressed by Clausi as a force which changes industry priorities for research:

> ...Some Americans' unrealistic attitudes toward our own country's food supply, attitudes which consistently thwart science and technology in their attempts to find useful solutions to world hunger problems....I am talking about the back-to-nature advocates, who believe that foods right off the farm are the only ones fit to eat. Their feelings are understandable, but they conveniently seem to forget that in our highly developed urbanized society, very few of us live close enough to the land to do that. Rather, we must depend on an efficient food processing and distribution system to supply our needs. [12]

L. P. Schertz at the 1977 Outlook Conference states:

> Environmental issues are here to stay. But energy and growth issues are also here to stay. The confluence of these problems causes conflicts:

production vs. quality of the environment, urban vs. rural America, and environmentalists vs. energy developers. Involved are divergencies between costs and benefits of individuals and those perceived by society. Over many years our research and information systems have supported private decisionmakers. Now, public decisionmakers need expanded support with biological, physical, and economic research. This support should be equivalent to research support provided in the past for private decisions in U.S. agriculture and public decisions on agricultural policy. Some adjustments have been made. But further re-orientation and expansion of our research and related information systems are needed. In this way both environmental and growth aspects of problems can be effectively considered and social, as well as private costs and benefits of alternative decisions can be accurately evaluated. [31]

Schertz goes on to point out that these areas of concern have become institutionalized in a series of legislative acts, regulations, and agencies such as the Council on Environmental Quality, the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the National Commission on Water Quality. [31]

Jane S. Wilson of Consumer Interest at the 1977 Outlook Conference states:

I'm not telling you anything new when I say that Government needs to know more about how the people out there are thinking, what their needs are. Consumer activities and their counterparts in industry need to know too. The climate is right for interaction. Whatever you do to help improve the consumers lot can only be enhanced by your participation in this process. [31]

The production and use of safe agricultural chemicals continues as a serious issue. Dr. Wittwer states:

There is an unceasing demand for absolute safety. We can also now detect that which we cannot interpret. The lack of scientific input into decisionmaking that is increasingly controlled by lawyers and politicians is a national problem. [17]

The following statement by M. T. Ouye helps to draw the issue from the agricultural researcher's perspective:

Pests continue to reduce the potential yield of our agricultural commodities by about one-third, despite the sophisticated pest control technologies of today, and an annual expenditure by farmers of about $5 billion for pesticides and application costs. Without use of pesticides, the total output of crops, livestock, and forests combined would be reduced immediately by at least 25 percent; the price of farm products would probably increase at least 50 percent; and consumers would be forced to devote 25 percent or more of their income for food.

Manufacturer's cost to successfully develop and register pesticides have have been rising steadily and has increased 5- to 10-fold during the past decade. The 1972 Amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) essentially changed a labeling law to a

comprehensive regulatory statute that more carefully controlled the manufacture, distribution, and use of pesticides. Effective pesticides that are no longer available include aldrin, chlordane, and heptachlor against corn insects; DDT against many insects, including gypsy moths and pink bollworm; and mercury compounds against fungi. Under the provisions of FIFRA, every pesticide must be reregistered every 5 years. EPA has established a process for issuing a Rebuttable Presumption Against Registration (RPAR) for a pesticide when there is evidence it may generally cause unreasonable risk to man or the environment. EPA has identified more than 100 pesticides for RPAR, for some of which no alternative pesticides are available at present; e.g., Mirex against imported fire ant. Others on the RPAR list are key ingredients of our most effective formulations, such as carbon tetrachloride, and some such as ethylene dibromide, are among our most effective fumigants. With the rising developmental and registration costs for new pesticides, industry is placing emphasis on protecting those pesticides presently available in lieu of developing new ones. This appears to be true especially for those pesticides with large volume sales. The public sector will therefore have to develop data necessary for registering minor and special use pesticides. The number of uses falling into these categories continues to increase as the costs of development and registration increase. The number of new pesticides registered for use during the 5-year period 1970-74 totaled 27, which included 11 herbicides, 6 insecticides, 3 fungicides, and only 2 nematicides. Insecticides and fungicides become obsolete because pests eventually develop resistance to them, and frequently within 3-10 years of extensive usage. Thus, because of regulatory and biological reasons, the insecticide and fungicide arsenal is being depleted more rapidly than it is being replenished, and industrial research on new fumigants has virtually ceased.

Research costs to develop pest control technologies have been rising rapidly not only due to inflation but to increased Federal regulations as cited above. Another example is Public Law 85-929, the Food Additives Amendment to the Federal Food, Drug, and Cosmetic Act, September 1958, which will increase the cost of variety development. The amendment defined a food additive as anything added to food with two exceptions not otherwise covered in the act. One exception includes substances considered as generally recognized as safe or GRAS. FDA can challenge the GRAS status of any new plant variety if its content of nutrients or natural toxicants differs signficantly from previous grown varieties. This is identified in Section 121.3, Title 21, Code of Federal Regulations, published in the Federal Register, June 25, 1971.

The above challenges will have to be met by substantial research thrusts on pesticides per se, on alternative methods, and on integration of various methods into more enduring systems of pest control.1/

Changes in priorities, redirections to meet new challenges, and availability of funding can pose serious discontinuity problems for the agricultural research system. Some feel systematic scholarly research is adversely

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1/ M. T. Ouye, PACS, SEA, USDA, January 14, 1977.

affected in the rush to solve new problems. There are many instances where the efforts of strong and effective teams of scientists have been destroyed by the need to divert funds from established programs to provide needed funds for other areas. For example, until the late 1960's, one agency had a group of six to eight scientists working on symbiotic nitrogen fixation. Even though the group was productive scientifically, support gradually declined because of the low costs of nitrogen fertilizer and the stigma attached to production research at that time. Seven of these scientists are still employed by the agency. Five are scattered over the U.S. in different groups investigating various aspects of pollution and wastes. Only two work on aspects of nitrogen fixation, and until recently, at very low levels of support. Over the past several years, one of these scientists maintained and enlarged the world Rhizobium collection largely on his own initiative.

Another area of expertise dismantled during this same period is in the field of nitrogen transformations, how nitrogen, once fixed, cycles through the environment and eventually returns to the atmosphere. Agricultural scientists once totally dominated this field, but, excepting some pollution aspects, abandoned it for the same reason they left nitrogen fixation (inadequate funds). Now, as the true importance of the nitrogen cycle is becoming understood outside agriculture, large numbers of scientists are reentering the field, especially those concerned with ecology and environment. Recent meetings and literature suggest they soon will catch up to where agricultural scientists left off 10 to 20 years ago.

These examples point out the disruptive forces involved in inadequate or discontinuity in funding coupled with higher demands for research in other areas. A view held by one agricultural scientist is as follows:

> The power of science arises from the single-minded pursuit of knowledge by those who devote their lives to it. The many years spent in education and training can be wasted by these kinds of disruptions. More years are wasted putting teams back together again when new breakthroughs occur or someone guesses wrong. Unless these changes are programmed carefully, this power is dissipated and human and financial resources are wasted.1/

K. R. Farrell described the current policy setting as one of persisting and heightening conflict between traditional agriculture and other interest groups: [49]

> Examples abound: the clash between agricultural and environmental protection interests, between agricultural and urban interests in development and use of water and energy resources, the enactment of stringent standards related to food quality and safety, and export embargoes of agricultural commodities to control domestic food prices. Although we continue to rely principally upon market mechanisms to resolve such conflicts, at the same time we involve the government to alter outcomes or remedy deficiencies of the market. At the very heart of these issues are the economic questions: Who gains and who loses from government involvement in our economic system? What is the net benefit to society

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1/A. R. Grable, PACS, SEA, USDA, January 18, 1977.

of that involvement? If there are positive net benefits, can losers be compensated such that benefits are not offset? What are appropriate measures of economic gains and losses and in what time frame?

These heightened conflicts are not transitory. They seem likely to broaden and intensify as policy trade-offs become more sharply defined in a context in which our capacity for economic growth at rates of recent decades, or even its desirability, is in question.

Inflationary Costs, Adequacy of Science and Technology Reserves, and Funding of Research

Essentially every study or report addressing adequacy of funding of agricultural research called for its strengthing by way of increased funding. This is not altogether surprising coming mainly from the science and technology community. However, the views and reasoning behind these studies and reports strike a familiar pattern from all persons involved, including the Congress and persons testifying at Hearings and from users of agricultural technology. [1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 20a, 21, 22, 23, 28, 28a, 29, 30, 36, 37, 38, 42, 43, 44]

T. W. Edminster is concerned about the challenges that lie ahead:

> The U.S. is no longer the leader in research on key processes that control crop productivity--photosynthetic efficiency, biological nitrogen fixation, and unconventional approaches to plant breeding. The first two are said to be the most important biological processes on earth. One is a source of all carbohydrates and calories consumed by man and the fossil fuels we are now using so lavishly. At present, this country is spending less than $10 million for research on photosynthesis although billions of dollars are being directed toward energy research. Nitrogen fixation provides a raw product for protein synthesis. The nation spends less than $5 million on this process. To quote recent testimony before the House Committee on Agriculture, "Expanded research efforts in these three areas would literally add to the resources of the earth--the processes are nonpolluting, they are renewable, no limits can be ascribed, and the acquired technologies are nonpolitical."

The Long-Range Study in 1966 points up difficulties in deciding how to determine balance or allocations between Federal and university laboratories. Recommended levels for research in the report were made for total programs without a breakdown as to the respective contributions of the experiment stations or the Department. The study assumed that this would be done later on after an indepth study was made of each problem area and a determination made of where and by whom the research could best be done. [1]

T. W. Edminster expressed concern over the poor prospects of publicly supported agricultural research to meet future demands at current levels of funding: [12]

> Frankly, as agricultural scientists and engineers, we are becoming increasingly concerned about the real likelihood that we cannot sustain the rate of flow of new technology we have enjoyed in recent years,

despite our great confidence in the agricultural research system in the U.S. This concern is based on: (1) general slippage of research capacity during the past 10 years due to inflationary costs; (2) higher constant dollar costs in researching increasingly complex problems; (3) new and greater responsibilities to maintain and improve the environment; (4) increasing demands for safe nutritionally acceptable foods; (5) increasingly regressive pressures placed on high yielding plants and animals by the environment, insect pests, and diseases; (6) new technology demands caused by high energy prices, use of marginal lands, consumer demands, and inability to use certain existing technology; (7) persistent and formidable yield barriers; and (8) erosion of technology reserves.

During the period of readily available agricultural production capacity, the argument was forcefully made that it did not make sense to increase agricultural research at a time when food and feed reserves were so large. The logic of that argument gave little weight to the timelag between research expenditures, research results, technology development, and adoption, and yet it was sufficient to stablilize expansion of research programs.

The contribution that agricultural research can make to safe and adequate food supply, reasonably priced, must be one of the highest research priorities. To achieve this objective will require an increase in priority for research well above 10 years ago and above the present 2 percent share of the Federal R&D budget.

Concerns about Narrowing of Base of Support in Congress

The following statement is taken from the publication "Industry Views of the Role of the Federal Government in Industrial Innovation," Graduate School of Business, the University of Texas at Austin, 1976:

> Agribusiness is also concerned about dwindling representation in Congress because of the population shift from rural to urban areas. Without governmental aid it will never be able to achieve the goals expected of it, and without the necessary political power, agriculture will be unable to procure such aid. The Federal Government should increase its funding of research activities by the USDA and further extend such participation to the various cooperatives and trade associations that exist today.

Concerns over the Adequacy of Science and Technology Reserves

Products of agricultural R&D depreciate and their applicability are not preserved indefinitely. Although widely applied at one point, most technologies gradually diminish in application over time because of several reasons, including natural regression of biostocks, such as hybrid wheat lines or animal blood lines, and the introduction of a new technology that negates the usefulness of other currently applied technologies and practices. A study by NSF indicates that the average period from discovery to obsolescence may be as short as 12 years. In our technology-oriented economy, one actually structured to induce technological obsolescence, this is not at all an unbelievable lifetime.

In 1969, B. T. Shaw indicated some areas that already have used a large part of our backlog of research information in reaching present yield levels. Annual production of eggs per laying hen was believed to be close to maximum production using all available research information, even in 1965. For other commodities, such as wheat, corn, and sugarcane, yields produced by farmers still are lower than research yields. However, farm yields in some instances have leveled out after past infusions of new technology (new varieties and chemical weed control, for example). In some cases it seems, we have reached or are approaching a "yield barrier":

> Tremendous effort is required in wheat research just to stay even. New diseases develop almost as fast as the scientist can develop new varieties --it takes a lot of running to keep from falling back in sugarcane production research.1/

Shaw's data shows:

> We have not been turning out new research findings in the last 10 years at a rate equal to that at which they are being used. For every commodity, farm yields have been increasing faster than research yields.1/

The "treadmill" requirements of research to sustain current levels of production are typified by the rate of turnover of wheat varieties. Of 263 wheat varieties grown in the U.S. in 1969, over 50 percent (138 varieties) were introduced during the preceding decade; 32 percent were introduced during the preceding 5-year period. On the other hand, of the 177 varieties grown in 1959, 5 percent had disappeared by 1964 and 30 percent by 1969. Approximately one-fifth of the varieties grown in 1964 disappeared by 1969.

> If we assume that the 5-year depletion rate is 20 percent and that the new introductions (5-year period) will make up 30 percent of the available complement, we can anticipate that about 300 varieties will be available during the 1974 growing season. This estimate also assumes that there has been no erosion of our germplasm base or research effort during the past 5 or 10 years.2/

There are numerous indications that yield rates in important crops and farm animals are at, or are approaching, serious barriers including yield per acre of soybeans, wheat, corn, sorghums, cotton; egg laying rate in poultry; feed conversion efficiency in most farm animals; and fertilizer use efficiency by plants.

In a recent U.S. News and World Report (November 8, 1976), T. W. Edminster stated:

1/An Analysis of Agricultural Research in Relation to the Increasing Demands for Agricultural Production. Report 104, ARS, USDA, 1969.

2/Via L. L. Jansen, ARS, USDA.

> Agricultural research is one of the most critical problems facing us today. We cannot afford to be complacent just because of some possible food surpluses in this country in the next few years. We need to look ahead 20 years.

This article goes on to state:

> Corn yields more than doubled when farmers adopted hybrid vigor and then shot up again with a widespread use of chemical fertilizers. But they have remained static through the 1970's. In 1972, for example, farmers produced an average of 97.1 bushels per acre, up from a 28.9-bushel yield in 1940. But in 1975, corn yields averaged only 86.2 bushels, and the USDA estimates this year's yields will average 82.7 bushels per acre.
>
> Yields for wheat, soybeans, rice, sorghums, and cotton follow a similar pattern.
>
> Wheat farmers, who still do not have an economically acceptable hybrid vigor after 30 years of research, have seen yields increase only slightly from the 1960's average of 26.1 bushels per acre.
>
> Yields for soybeans, which do not respond dramatically to fertilizer, have increased a bit in recent years only because farmers started planting them on better land as they emerged as a major crop.
>
> Agricultural researchers believe that some improvement in crop yields can be expected, but at a much slower pace than in the past.

In the same report, G. W. Salisbury stated:

> The rate of technological advances in the past was much faster than it can be in the future. Although we are still on an upward trajectory in food production, the curve is beginning to flatten out.
>
> Besides trying to develop new, high-yielding crops, researchers must wage a continuing battle just to protect past achievements. Plant insects, viruses, and bacteria are constantly changing genetically; and each change poses another threat. Scientists must counter with new plant varieties resistant to the altered disease or with chemicals lethal to changed insects.

In the same article T. W. Edminster added:

> The average life of any new variety is 5 years before disease, germs, and insects adapt and mutate to attack the plant. Much of the current research effort is just maintaining the status quo.

A report by the National Science Board (Science Indicators-1974) indicates that, although still strong in comparison to other nations, U.S. leadership in all science and technology appears to be eroding. Highlights of their findings include the following:

The proportion of the Gross National Product spent for R&D in the U.S. has declined steadily in the last decade to 2.4 percent, while growing substantially in the U.S.S.R. (3.1 percent), West Germany (2.4 percent), and Japan (1.9 percent).

Although a majority of a sample of major technological innovations of the past 20 years were produced by the U.S., the proportion declined from 80 percent in the late 1950's to 55 to 60 percent since the mid-1960's. Japan and West Germany showed noted increases.

The U.S. had a favorable but declining "patent balance" between 1966 and 1973.

U.S. funding for R&D has not kept pace with inflation. Although Federal funds for R&D increased in constant dollars in all but 2 years between 1960 and 1974, reaching 17 billion in 1974, funding in terms of constant dollars peaked in 1966 and was down 19 percent in 1974 to less than 12 billion--the level of funding in 1963.

The proportions of R&D funds allocated to basic research, applied research, and development have remained nearly constant since 1965, with development receiving 64 percent, applied research 23 percent, and basic research 13 percent.

The Economic Report of the President, March 1976, states:

New or improved technology plays a central role in increasing productivity and thereby national welfare. Throughout the post-World War II period the U.S. has been a recognized leader in scientific research and the application of new technology. But recent declines in the U.S. real expenditures on research and development (R&D) have caused some concern that the U.S. has been lagging in this important area, relative to both its major foreign competitors and to its own historic experience.

In testimony before the Subcommittee on Science, Research and Technology, Dr. G. S. Pound stated: [12]

Information use is outpassing information production. From 1887 to 1940, we made greater deposits in our storehouse of knowledge than we made withdrawals. Since 1940, however, we have put to use virtually all knowledge and problems of production loom on the horizon. There is growing concern that our agricultural productivity may be plateauing.

It is disturbing that our national priority for food is such that in FY 1976 our federal government proposes to spend only 1.7 percent of its total R&D dollars on food research.

Concerns About Impact of Inflationary Costs

Agricultural research institutions and agencies have indicated considerable concern over what they view as a serious slippage in level of research support over the past 10 years, caused by rising inflationary costs since the mid-1960's. For example, USDA budgets (appropriations) for agricultural

research increased from $253 million in 1966 to $510 million in 1977, an increase of 101 percent in actual dollars. However, when expressed in constant dollars, this represents a 5 percent decrease. The constant dollar change was negative for two agencies: -18 percent for FCS and -12 percent for ARS. These USDA appropriations are shown in actual and constant dollars for FY 1966 and FY 1977 in table 1 in the body of this report, and in actual dollars for each agency by year in attachment VI.

The impact of these inflationary costs has been most severe in those program areas for which new appropriations were least. These trends have been examined by program areas based on CRIS data and the results appear in attachments VII and VIII. Attachment VIII indicates that percentage increases in constant dollars from 1968 to 1975 were lowest for Marketing Systems; Products, Processes and Quality; Protection; and Natural Resources. Production and protection research combined did not keep pace in constant dollar support with all other goals. In the case of ARS where the constant dollar change for the total of all goals was -5 percent, the change in production and protection was essentially zero, although support for natural resources declined 28 percent.

Concern about the impact of inflated prices on underfunding of base programs was considered of such importance by one study group, its first recommendation was for restoration of all research programs: [15]

> Costs of government goods and services other than salaries have more than doubled since 1966. In addition to usual government costs, agricultural research institutions and agencies have been faced with higher costs of livestock feeds and fuels for the operation of their experimental farms. The necessity of advanced research for increasingly sophisticated equipment has driven costs up still further. The result has been an increase in costs per scientist from $39,000 in 1966 to $77,000 in 1975, exclusive of construction, repair, and maintenance costs of research facilities. These actual costs have been escalating since 1974 at about 14 percent per year. They are slightly more for food and food related research ($78,000), and at least 50 percent more for animal research.
>
> For the universities, the burden of meeting these rising costs has been met far more by State appropriations than by Federal. The percentage increase in CSRS funds for the universities has been only one-half as large as the percentage in State funding. And despite the State effort, support for university scientists in terms of technicians and laboratory helpers has been reduced. Because of this, the time of highly trained researchers is less productive because they must perform tasks that could be done by technicians and helpers.
>
> Rising costs for USDA in-house agencies have been associated with the necessary reduction of more than 200 scientist years on research in progress. Even greater reductions in personnel ceilings, met largely through attrition, have created a serious imbalance in support help for scientists.
>
> The crippling effects of these costs on ongoing research was the reason the work group made restoration of support for <u>all</u> agricultural research

Table 1. USDA Appropriation for Research: FY 1966-77 ($ in million)

Agency	FY 1966		FY 1977		% Change	
	$Actual	$Constant1/	$Actual	$Constant1,2/	$Actual	$Constant
ARS	147.0	206.5	273.2	181.2	85.8	-12.3
CSRS	55.3	77.7	122.5	81.2	121.5	4.5
SRS	.4	.6	2.0	1.3	400.0	116.7
ERS	12.2	17.1	26.1	17.3	113.9	1.2
FCS	.8	1.1	1.3	.9	62.5	-18.1
FS	37.4	52.5	84.7	56.2	126.5	7.0
Total	253.0	355.3	509.8	338.1	101.5	-4.8

1/Constant dollars using deflators for Federal Government Purchases of Goods and Services (p. 191 Economic Report of the President, 1977)

2/Deflator is estimated as the average of FY 1975 and FY 1976.

its number one recommendation. Such restoration would bring about a major increase in the effectiveness of research in progress, and would contribute greatly to meeting U.S. and world food needs.

Furthermore, all future budget requests should include factored increases for base funding of sufficient magnitude to cover continuing inflation and the quantum jumps in cost of upgrading scientific equipment to keep abreast with rapid and sophisticated advances in science and technology. This recommendation is further elaborated in the following statements on dollar cost support per SY.

Food and food related research cost $78 thousand per SY (scientist year) in FY 1975. Assuming a 7 percent annual increase, which probably is conservative, the cost per SY would increase to $96 thousand for 1978; $102 thousand for 1979; $109 thousand for 1980 and $117 thousand for 1981.

Concerns About Level of Funding of Research

Numerous reports document specific concerns expressed by individuals or study groups about the inadequacy of level of funding to meet current and long-term needs for agricultural science and technology. For the most part, these were not "Carte Blanche" requests for increases--in most cases they were for areas of specific need. Two studies included a plan or general strategy for implementation. [1, 15]

In studies reviewed, several references were made to the USDA share of the overall U.S. Federal R&D budget. Figure 2 in attachment IX shows that the USDA R&D budget is in the order of 2 percent of the U.S. Federal R&D budget in 1977. This "share" has declined sharply from an estimated 39 percent in 1940, to around 2 percent in 1960. Figure 1 in attachment IX displays actual and constant dollar trends in 1967-77 for USDA and ARS.

Numerous specific examples and prevalent views in support of additional funding for agricultural research are given, such as the following:

An OSTP Advisory Panel chaired by W. O. Baker and Simon Ramo in "Draft Recommendations on Food and Nutrition" included the following in one of four recommendations: [44]

> Basic research in fields related to food production should be substantially expanded by allocating new funds to support relevant programs. A new unit should be established within the Department of Agriculture or the National Science Foundation to administer the funds proposed for this basic research program.

Assistant Secretary Long of USDA responded to Dr. Stever on December 15, 1976, strongly concurring in the emphasis given to basic research in fields related to food production. The Department also feels that the USDA should maintain lead responsibility in mission-oriented basic research to enhance food production because (1) basic research capability already exists in USDA and in cooperating universities, (2) the combination of applied and basic research benefit go together, and (3) the USDA-land grant university system already has major capability in followup on any basic research findings.

The Long-Range Study of 1966 recommended increasing agricultural and forestry research programs in the SAES and USDA by 38 percent for FY 1972, and 76 percent in FY 1977, over a base level of 10,330 scientists and engineers in FY 1965. [1]

The "Pound" Report recommended:

> That the USDA seek a greatly increased level of appropriations for competitive grants program, which should include support of basic research in the sciences (biological, physical, social) that underpin the USDA mission. These appropriations should be without commodity earmarking although they should not exclude commodity related research. They should be available to scientists in the USDA, in land-grant and non-land-grant public universities or colleges and in private universities or colleges, institutes, and other research agencies. The committee recommends further that this program be administered in such a way that research proposals are subjected to evaluation by peer panels of selected scientists drawn from those eligible for support, and that the administration should not be the same as that making allocation for USDA in-house research. [3]

Philip H. Abelson, in an article in the October 29, 1974, issue of Science, summarizes a recent report from the National Science Board and expresses his own concern about the declining support for the Nation's basic research efforts when measured in constant dollars. He notes a concern from the science and technology community, based on a response from 650 persons on these additional aspects of the R&D system (1) dependability and funding for research, (2) vitality of the research system, (3) freedom in the research system, and (4) confidence in science and technology. Abelson goes on to say:

> At one time basic research was rather well funded in industry, at least in many companies. Of late however there has been a sharp decrease in long-term support for fundamental research with more emphasis being placed on potentially quick-payoff activities such as improving existing products and cutting costs in their manufacture.

Industry faces another very difficult problem. Abelson believes that expenditures for environmental cleanup and compliance with safety regulations have the first call on capital funds of most companies. Additionally, there is a well-known empirical relationship in industry between funds for research and capital investment that is:

> ...for each $1 spent on successful research, $100 must be spent to bring a product to market. When long-term prospects for capital funds are dim, it is difficult to justify long-term basic research.

The Interim Report of the NRC Steering Committee supports increased funding for agriculture research with a statement: [11]

> We believe that an overall food and nutrition research budget increase, compared to FY 1974, of at least 50 percent in real terms over the next 2 or 3 years is needed to make a strong start on the new priorities,

and that a steadily rising expenditure trend is essential over the next decade and beyond to do justice to the purpose of reducing world hunger and malnutrition.

An NAS study in 1976 stated: [21]

Increases in the resource base can be achieved through study of materials improvement and conservation. Research in wood science and technology has been declining in the past 20 years...There are only eight major universities still pursuing important materials research and education in the field of wood science and technology.

The report of the Special Oversight Review stated: [17]

Representatives from all major segments of the agricultural research community seemed to agree that expanded and carefully directed research would be necessary in order to insure expanded food production in the U.S. and the world.

Recommendations of the followup Work Group to the Kansas City Conference included the following: [15]

In addition to the program increases, the level of Federal and State funding for agricultural research should be raised sufficiently to restore the 1966 level of support for ongoing research. The FY 1977 Federal budget proposals which help remedy this deficiency, should be supported. In addition, ARPAC should immediately develop hard data regarding the full magnitude of the funds required.

Over a period of four years the increases recommended for all 117 problems would amount to 2,031 SY's and $152 million in 1975 dollars. This increase is 27 percent of the total food and food-related effort by the USDA and State agricultural research agencies.

The report of the NRC Study on World Food and Nutrition stated: [16]

Starting with the US public system, there must be a general strengthening to make up for erosion which has taken place in recent years due to the stagnation in the real terms of funds. This should be followed by increased federal support for international research to be carried out by the traditional public agricultural research institutions at the federal and state level. Then an increased effort must be made to involve other elements of the U.S. research community and studies oriented to LDC needs. In addition, multilateral support for international and regional research activities and bilateral support for LDC national programs should be encouraged and enlarged...USDA food and nutrition research should be immediately increased 20 percent (approximately $120 million) over present levels and then be cumulatively increased at the rate of 10 percent per year in real terms for the next four years. These increases should be divided equally between: (1) USDA in-house research and Hatch formula allocations, and (2) a new high priority competitive grants research

program. Over a five-year period this will raise USDA food and nutrition research from the current level of $560 million to $1 billion in real terms from the present base.

Senator Talmadge instructed his staff last year to draft legislation that would achieve four main points:

First, achieve adequate funding for agricultural research,

Second, fill the gaps in our overall research effort,

Third, assure continuity and maintain the strengths of our current systems, and

Fourth, achieve better coordination of the effort and therefore a more cost-effective agricultural research program.

This has been introduced in the 95th Congress as Senate bill 272. [43]

To assure reasonable support for research, Senate bill 272 specifies that food and agricultural research funding should equal at least one-half of 1 percent of domestic expenditures for food plus one-half of 1 percent of gross agriculture exports.

A report by the Senate Committee on Agriculture and Forestry stated: [38]

> Greater emphasis on research is one of our principal long-term needs. If we are going to increase production to feed 80 percent more people in the world 25 years from now with our present land resources, it will be made possible through research and through application of capital. We have the machinery in USDA to do this, through the Agricultural Research Service and through experiment stations in 50 States.

Secretary Kissinger proposed at the World Food Conference in Rome in 1974 that resources for the international agricultural research centers be more than doubled by 1980. Further, he said that: [20a]

> The U.S. over the same period will triple its own contributions for the international centers, research in the LDC's, and in U.S. universities.

H. G. Stever, in an article in Steel Facts, Issue No. 2, 1975, states:

> While I believe strongly in the cooperative aspects of international science, I want to note the competitive side of the picture. There is no doubt that, though it remains strong, this country's leadership in high technology is being strongly challenged in many ways and in many parts of the world. There comes a time in every industry--and every country--when more basic and applied research is essential to bring totally new products and services--and even better old ones at lower prices--into the market-place. World conditions are telling us that time is here, if not past due.

The November 1975 Interim Report of the Steering Committee of the NRC Study on World Food and Nutrition states that there is an urgent need: [11]

> ...to move promptly onto a substantially high level of effort to expand the science base for improved food production technology without neglecting the continuing need for stronger efforts on applied research. Without basic research breakthroughs, the resource costs of feeding some 6 billion people by 2000 and possibly 8 billion a generation later will be higher, even if per capita food production rises; therefore the problem of producing adequate diets for those at the lower end of the income scale will be that much greater.

The report by the Senate Committee on Agriculture and Forestry states: [38]

> Current recommendations of the National Academy of Science indicate a need to increase agricultural food and nutrition research support in the range of 10 percent per year for five years. In addition, recommendations have been made for special competitive research grants in high priority photosynthesis, nitrogen fixation and plant genetics at levels of $50-$75 million per year.
>
> A national food policy would substantially increase funding for agricultural research with a goal of matching increased population with increased food production. The leadership for this must come from the Federal level.

The BARR (Board on Agriculture and Renewable Resources) report recommended: [8]

> A substantial increase in support for research directed toward the production, dependability and quality of the food supply.

The Special Oversight Report stated: [17]

> The USDA-State Agriculture Experiment Station system has the resource base necessary for the effective use of additional funds. Such resources include food training and knowledgeable personnel, systems of communication, facilities, and established programs for relatively stable sources of support.

David Hopper in one of 12 articles on food and agriculture in Scientific American concludes: [37]

> The relevant question for mankind, however, may not be one about investment return. It may rather be: What is the longrun cost of not initiating now a program of investing in man's future food supply? Water-resource development has a long gestation time before it yields benefits, and so do many other elements of agricultural modernization. Political leaders in both the rich and the poor countries have a short time horizon; they focus on immediate concerns. Yet future food supplies depend not on the application of more fertilizer to existing fields this year or next,

but on a joint and shared commitment by the developed and the developing countries to the long-term and expensive development of the world's untapped farm resources.

J. W. Symington reported:

In 1938, nearly 40 percent of all federally supported research was provided by the Department of Agriculture. For 1976 the USDA share is 2 percent, and there is a growing consensus among the Congress, the Administration, and the scientific community that this is not enough. This consensus has emerged from a debate on the current and long-range prospects for worldwide food and nutrition—and on the role that science and technology should play.1/

Technology Transfer to Developing Countries

Virtually all studies that addressed the challenge of increasing food supply for food deficient nations concluded that most of the food required must come from the developing countries themselves.

The NRC study on World Food and Nutrition reported: [11]

(The assessment of the World Food Conference estimated that the developing countries' demand for food would grow at an average rate of 3.6 percent between now and 1985.) We can hope that the rate of population increase will come down into the range of 1.5 to 2 percent over the next 15 to 20 years, but it may not. A reasonable assumption is that the developing countries will need an average annual increase in food supply of about 3 to 4 percent for several decades to effect a gradual improvement in nutritional status. The margin for increased per capita consumption will then depend on the rate of decline in population growth.

Meeting these demands for U.S. food supplies plus prospective continuing increased demand by other developing and developed countries will tend to raise food cost in the U.S. and may cause other strains unless the costs of producing food are simultaneously reduced substantially by productivity gains. Even if these problems are resolved satisfactorily, food imports from the U.S. by developing countries will continue to be limited by their ability to pay. It seems prudent to assume that net food imports from the U.S. over the next 25 years can supply but a modest fraction of the increase in food consumption required in developing countries to meet the expected increase in demand and to improve the nutritional status of low income families. An increase proportionate to this requirement would double U.S. food exports to these countries in 20 years.

Thus 3 to 4 percent annual increase in food consumption in the developing countries depend on parallel increases in their own productivity.

1/J. W. Symington, Science in Political Context: One View by a Politician. Science: Volume 194, pp. 402-405, 1976.

The University of California Food Task Force reports: [4]

> The distribution of world food supplies will remain a more serious problem than total world crop and animal production.
>
> Meeting food production needs during the next 15 years of the 20th Century will depend upon accelerated adoption of known methods, development of new technology, and, indeed, some real breakthroughs. Planning, basic and adaptive research, and the development of effective vehicles for international cooperation are imperative if food production technology is to be available when and where needed. Improved methods for timely monitoring of world food production and utilization will also be required for effective planning.
>
> New technology to increase production, if patterned after developed countries, is capital-intensive and labor-saving. This approach is not directly applicable in densely populated countries that depend on subsistance agriculture.
>
> Increasing energy use in agriculture should be viewed with greater concern at all levels. Procedures should be developed to preserve and extend the availability of fossil fuels for those vital purposes for which no feasible alternative now exists. Alternative nitrogen sources should also be explored.

The Iowa World Food Conference reported: [19]

> There is a wealth of research and technology already existing in many areas related to food and population problems. Increased emphasis should be placed on procedures and systems that will make these data retrievable, adaptable, and usable under varying conditions to meet divergent needs.
>
> The following were among the more specific suggestions for making research and technology more relevant to user needs: 1) Involve ultimate users in determining technology needs, 2) Require researchers to live and work with ultimate users for specified periods of time, 3) Facilitate or create more effective "linker" roles between ultimate users and research, 4) Place increased emphasis on adapting research technology, 5) Analyze "technology" currently being used by indigenous groups, and 6) Make sure technology recommended is very specific and adapted to farmer's resource and management competence.

At the Special Oversight Hearings, Sterling Wortman outlined numerous supporting research needs in which the U.S., and especially USDA, should be more deeply involved relative to world food problems. These include 1) plant exploration, 2) selected animal diseases, 3) crop plants in the tropics and subtropics. He feels the U.S. should at a minimum have within 3 or 4 years one major research center in the Caribbean oriented toward cooperative work with Latin American nations, and one in the Pacific concerned with cooperative work with nations and institutes of Asia, 4) human diseases, and 5) more fundamentally, purposeful work on major food, fiber, and animal species. He feels the U.S. should "maintain a strong bilateral technical assistance program."

Wortman provided to Congressmen Thornton and Symington, at their request, an answer to the question, "In your opinion, is there adequate communication of research results between USDA and the international centers?" Wortman replied as follows: [12]

> Communication of research results between the USDA and the international centers generally is weak. The USDA has had almost wholly a domestic orientation. Its funds for foreign travel or for participation in international cooperative work have been meager, I am told, for the past two or three decades...It is time that the USDA be given the mandate, the funds and the authorization to recruit a substantial number of first-rate young scientists to make the U.S. once again a leader in international agriculture.

There are constraints to agencies and employees in carrying out foreign assignments. Many such assignments are not attractive to U.S. agricultural scientists or to their supervisors. Obtaining full credit for such assignments can be a problem; and supervisors often have difficulty in filling in behind employees while they are away. In the case of Government employees, there may be classification constraints and difficulties involving return rights. Agencies like ARS are considering development of a cadre of experts to sustain its international program activities and to developing a foreign assignment planning system. However, special authorizations are required.

One report places emphasis on the gap that exists between actual and potential crop yields in developing countries. It states:

> Much new area can be brought into cultivation and much present cultivated area can be cropped two or three times per year. Substantial investment will be required to develop new lands, build irrigation systems, and manufacture fertilizers, pesticides, machines, and other means to exploit the physical basis for agricultural production. Governments must have the commitment and the will to pursue aggressive agricultural development policies in land reform, input distribution, credit, marketing, and price policy. Equally important, research must now be supported on a much larger scale than in the past to develop the technologies by which to power agricultural growth.1/

A comprehensive study of the World Food Problem was made in 1967 by the President's Science Advisory Committee. The report was published in three volumes. Several of the findings follow: [2]

> The transition from traditional farming to modern agriculture will be difficult and expensive for the hungry nations but it is absolutely essential if their food needs are to be met. There is no alternative.

1/R. W. Cummings, Jr. Food Crops in the Low Income Countries: The State of Present and Expected Agricultural Research and Technology, The Rockefeller Foundation, May 1976.

Critical to the success of all of these measures, however, is the necessity for adaptive research needed to gain an understanding of the principles governing plant and animal production under the conditions, soils, and climates existing in the developing countries.

The products of technology and "know-how" cannot be transferred directly to the developing nations. Many plant varieties transferred to different climates fail to flower or set seed if, indeed, they survive at all. Livestock may become nonproductive or die. Adaptive research must be accomplished within the developing countries.

...the U.S. must assume leadership of the free world and all of its international institutions in a coordinated, long-range development strategy for raising the economic level of the poor nations, thereby meeting the threat of hunger, increasing the volume of world trade and economic activity, and contributing to the achievement of the goal of ultimate importance, a lasting peace.

Several recommendations are provided by the World Food and Nutrition Study and the Interim Report:

The United States should establish one or more centers to conduct research and train scientists in problem areas important to agriculturally developing nations but not of major importance in this country. [8]

Continuing support should be provided for international agricultural research centers as now coordinated by the Consultative Group for International Agricultural Research. [8]

The U.S. should mobilize more of its research capabilities and supporting finance to help strengthen all three echelons of existing and new international R&D network that address high priority global problems; i.e., developing country research establishments, international research centers, and supporting U.S. research activities, as well as the linkages among them. [11]

The U.S. should establish, sustain and make strong use of legislative authority, such as the proposed Title XII of the Foreign Assistance Act, and of appropriate research budgets throughout the government to provide continuity of support at rising levels for multiple forms of U.S. research involvement on problems of world food supply and nutrition. [11]

The U.S. (USDA and AID) should establish a specific clearinghouse and financing mechanism to facilitate individual American initiatives or responses to overseas initiatives that would link U.S. research activities with those of international R&D network. [11]

The U.S. (USDA and NSF) should institute a program of extramural grants to draw a wide range of the best U.S. scientists to research on food and nutrition problems, combining individual scientific initiatives within a mosaic of activities furthering broad program goals. [11]

Philip H. Abelson notes the complex and interactive forces surrounding the production and distribution of food on a worldwide basis: [36]

> In many countries, politics dictate low prices for food for the urban poor. The low prices are maintained at the expense of the rural poor and this often leads to exacerbation of the problem. Finding themselves unable to make a living, the rural poor flock to cities.
>
> Because of low prices, farmers cannot afford to buy fertilizer, and this further holds down production. The acute problems tend to occur in the developing countries where population growth and increased production often run close races.

Abelson and Sprague feel the rest of the world may learn much from the food production experience in China, which utilizes less land and feeds a population nearly four times greater than the U.S. Abelson states: [36]

> Key factors are irrigation and transplanting techniques that permit as many as 12 crops of vegetables to be grown annually on some plots of land.

W. D. Hopper concludes: [37]

> The poor countries can feed themselves if their agriculture is modernized and their rural economies are restructured. That requires infusions of technology and capital from rich nations.

The Special Oversight Report on Technology Transfer to the Organization of Petroleum Exporting Countries made recommendations including the following: [51]

> The transfer of technology and the provision of scientific and technical assistance from the United States to countries with large amounts of natural resources such as petroleum, natural gas, metals, and other raw materials can benefit both the United States and the receiving country.
>
> Technical assistance by the United States Government to the developing, self-sustaining nations should be provided on a reimbursable basis.
>
> With a few exceptions, such as sensitive military and nuclear technologies, the United States should be prepared to provide a broad range of training, technology, and know-how to the resource-rich, developing nations.
>
> A lead agency should be designated with responsibility for reimbursable scientific and technical assistance to the rapidly developing, self-sustaining nations, and coordination between United States Federal agencies should be improved.

Small Farms and Part-time Farmers

In a study of small-farm operations in 1975, GAO defined a small-farm operator as: [45]

...a person who (1) is under 65 years of age, (2) works off the farm for wages less than 100 days a year, and (3) sells less than $20,000 of agricultural products annually. We recognize the limitations of using such general criteria for this definition. However, the criteria permit a general distinction to be made between (1) farmers in their productive years who may depend on profit from the sale of farm commodities as their main source of income and (2) other people with farm sales living in rural areas.

This GAO study was critical of the Department stating: [45]

Although some publicly supported extension and research projects have related to the needs of small-farm operators, the Department and land-grant colleges have not made a concerted effort to solve problems impeding the economic improvement of small-farm operations. Also they have not adequately (1) evaluated the economic and social impacts of production-efficiency research nor (2) determined the assistance that small-farm operators need to plan for and adjust to changes brought about by such research.

The study recommends that the Department: [45]

Examine the potential for research uniquely designed to improve the economic position of small-farm operators and, if such potential exists, consider the priority of such research in relation to other federally funded agricultural research.

Establish procedures for (1) evaluating the economic and social impacts of future research that could greatly change the productivity, structure, and/or size of existing farms, and (2) determining the assistance small-farm operators would need to plan for and adjust to the resulting changes.

The Department responded to the GAO report by stating, in part, that small-scale agriculture is well supported by agricultural research and identifies such areas as fruit and vegetable production and support for small marketing and processing firms. The Department questions the definition of small farms in the GAO report and responded in part:

...available technology and efficient management practices have not been the primary limiting factors in the improvement of the economic position of small farmers. Other limiting factors include availability and access to capital and farmland in appropriate quantities, location, and prices to small farmers.1/

An unpublished report of a study by ARS concludes:

The persistence of small farmers and the reversal of the recent rural-urban migration indicates that more emphasis on research that would enhance the well-being of small and part-time farmers may be warranted.

1/Statement accompanying letter from Secretary Butz to Honorable Jack Brooks, Chairman Committee on Government Operations, November 1975.

The cost effectiveness of such research compared with other methods of aid to rural people, or with other types of research, is a matter outside the scope of this committee. The justification for such actions will be less economic than social, and will represent a deliberate effort to provide a stronger technological undergirding for small, subsistence, and part-time farmers and the services that support them. Such new technology may be more readily transferable to small-scale agriculture in developing countries.

Much of the difficulty in talking about small and part-time farmers lies in their definition and in distinguishing this group from family farms. Don Paarlberg defines a family farm as:

> ...one on which the greater part of the labor and decisionmaking is supplied by the farmer and his family. Thus measured, 95 percent of our farms are family farms, a percentage that has been unchanged for several decades. These family farms produce about two-thirds of our farm production, a percentage that also has been rather stable over time.1/

Paarlberg feels the family farm:

> ...is a very durable institution. It has survived war, depression, inflation, and natural disaster. With a few highly visible and much publicized exceptions, it has thus far adapted itself very well to a technological revolution.1/

One of the areas recommended for increased emphasis in the Special Oversight Review is for: [17]

> Research on high-yielding systems of agriculture and other types of research which would benefit small-scale farm operations...It appears that insufficient effort is being expended on research which would enable the smaller farm units to remain competitive with large-scale production units. Three major aspects of this problem justified this concern.

This study reports that short-term production efficiency should not be the supreme goal of agricultural research. The feeling behind this is that the human being is an important "resource" which must be considered in the trade-offs of various types of agricultural research. The report suggests that it would be dangerous, both in this country and abroad, to embrace the most simplistic "economic" solution at the expense of other social values.

Research needs in support of home gardening are also stressed. The report goes on to state: [17]

> The one Federal program specifically addressing home gardening is within the Bureau of Outdoor Recreation of the Department of Interior. Considering the value of this activity for providing high-quality, low-cost food to millions of Americans, for educating numerous citizens in the science and the art of agriculture, and for instilling an increased

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1/Congressional Record - March 22, 1976.

respect for the resources of our country's abundant food supplies, the agricultural research community should recognize this opportunity to contribute actively to a larger effort...This type of agricultural research may provide one of the most effective means for solving the world food problem in the sense that technology could be generated that may be of direct use to a small-scale farming operation in developing countries.

Charles Romine, Mid West Research Institute, feels that USDA is not doing all that it could in the research areas that would benefit the small, independent farmers: [12, 17]

> I think that with all the touting of the support for the family farm that is going in this country USDA has done very little to insure that the family farm would be preserved. Technological developments, such as large machines that are vastly expensive, are extremely difficult for a small farmer to buy. Number one, he often doesn't have the credit base to borrow the money, and often finds it difficult to make the payments. I think what we need to do is to decide whether we want to preserve the family farm. I mean, is there a good case for preserving it? Maybe there isn't.

Several of the witnesses also emphasized that such technologies do exist, but many of them are more highly developed in countries other than the U.S. Dr. Sterling Wortman stated: [17]

> Much is being learned abroad about organization of systems to benefit small farmers and to promote rural prosperity - both on farms and in rural trade centers. Again with a few exceptions, our scientists and institutions are not involved or even able to be abreast of such developments. They could be, of course, if given Federal funds to allow certain of them to participate actively on a continuing basis.

The following are remarks by H. G. Stever on science and technology policies in the decade ahead appearing in the Congressional Record - Senate, November 3, 1975:

> We hear much talk these days about diseconomies of scale and that small is beautiful - raising fundamental questions about the efficiency and manageability of large systems. These questions must be faced and answered in the years ahead.

E. F. Kaitz and C. A. David report at the 1977 Outlook Conference as follows: [31]

> There has been a slight but steady growth in the number of households with fruit and vegetable home gardens over the past few years. Findings indicate that about 43 percent of the households surveyed planted a garden in 1974. This projects to around 30 million households in the 48 states surveyed; 46 percent in 1975 (approximately 33 million households); and 48 percent (approximately 34 million households) either had already planted or intended to plant one in 1976. This suggests that the interest

in home fruit and vegetable gardening generated in the United States 3 or 4 years ago amid fast-rising food prices may be established and is not necessarily transitory.

Around 85 percent of the 1975 gardens were located in the household yard.

The tomato was the most popular vegetable grown in the 1975 home garden - about 95 percent of our garden households grew them.

We investigated home canning or preserving as another way to utilize homegrown fruits and vegetables. Thirty-four percent of the households canned or preserved fruit or vegetables in 1975 whether or not these came from their home gardens or they even had a household garden.

The incentives for gardening, canning, and freezing are diminishing for those simply trying to save money as employment opportunities and incomes improve along with increasing stability in food prices. For the majority of gardening households, preference for their own produce and recreational enjoyment might tend to perpetuate gardening even in better economic times. As long as such households remain loyal to their motives, there is likelihood of a major decline in home gardening activities.

Chapter IV - RESEARCH PROGRAM AREAS OF SPECIAL CONCERN

General

As we have reviewed the numerous studies, reports, and other documents appended to this statement, a number of points stand out:

- U.S. and world population and the corresponding demand for food will continue to increase well into the 21st century regardless of how effective population control measures may be.

- Whether incremental increases in food production resulting from more effective use of present and developing technology and present levels and direction of research activity will be adequate to provide for the effective demand for food beyond 1985, is uncertain because of so many critical and unknown factors.

- The era of general food surpluses may be over. Bumper years, primarily the result of favorable weather and climatic conditions in major food-producing areas, may result in short-term surpluses; but in other years, unfavorable weather will result in increasingly serious food shortages. Food prices are likely to be both high and highly variable unless supplies can be reasonably stabilized.

- The most likely means of assuring food adequate to meet the needs of expanding populations and increased effective food demand, and still maintain reasonable domestic food prices, is more rapid development and adaptation of new technology. This in turn depends on a level of research adequate to provide the basis for the required new technology.

It seems quite clear that we are using up our reserves of research and technology knowledge faster than we are replenishing it both in the U.S. and worldwide. The rate of increase in productivity of food crops has shown disturbing leveling-off trends; this at a time when we are faced with the need to greatly increase world food production. Assistant Secretary Long has indicated that by the year 2000, we will need one-third more food just to meet the demand of our own expanding population [12]. In addition, we will need to double our exports in order to meet world food needs and maintain our balance of payments. Agricultural exports must provide much of the foreign exchange necessary to meet the costs of imported oil and gas.

There is a consensus in the various reports that we must increase the rate at which we are making advances in agricultural research in order to at least maintain, and preferably to increase, the reserves in our storehouse of knowledge. We also need to find ways to speed up the development and adoption of new technology.

The amount we are willing to invest in a stronger and more productive research and development system in agriculture will be governed by public perceptions of the seriousness of the world food problem, the rapidity with which shortages will develop, the alternatives for coping with shortages, how much we can afford to spend to prevent future major world food crisis from developing, and the relationship between food supplies and political stability.

A brief comparison of two possible alternatives indicates that greatly increased levels of agricultural research and technology development and transfer are likely to lead to (1) sharp increases in productivity of crops and livestock, both in the U.S. and in the developing countries; (2) increased capability for the developing countries to provide more of their own food requirements and for the U.S. to meet its own domestic needs and have supplies available for export; and (3) relatively stable food prices.

At the other end of the spectrum, maintenance of existing levels of agricultural research, and technology development and transfer, or continued erosion of these levels, are likely to lead to (1) a leveling off or even a decrease in productivity of crops and livestock; (2) a widening gap between food supplies and worldwide food needs with, at best, increased hunger in the world, and at worst, massive famine and starvation; and (3) sharply increasing food prices as demand exceeds supply.

What we invest in a stronger research and development program can be likened to an insurance policy. The more we put into research, the more protection we have against high domestic food prices and reduced agricultural exports or, worse, even higher domestic food prices associated with worldwide food shortages or famine.

From the reports, we have gleaned and identified in the following pages those research program areas, problems, and recommendations judged to be most pertinent in enabling the U.S. and world agricultural research community to develop a broader, more comprehensive, and more directly relevant program of research to meet the world's food and fiber needs in the coming decades.

Two reports merit special emphasis. Volume I of the report of the Kansas City Conference presents the results of a study of research needs and priorities carried out by 167 delegates representing a wide range of research areas. In addition, 215 other participants were asked to take part in the evaluation. A total of 89 research need areas were evaluated and rated by the delegates and other participants. The priority ranking of these need areas is shown in attachment X. The "top 10" research need areas by priority are identified as follows: [9]

Research Need Areas	Average Rating
Energy	4.73
Soybeans: Production	4.58
Water	4.53
Basic problems in plant growth and reproduction	4.51
Nutrient requirements	4.45
Production inputs and services	4.43
International development: Food production technology and resource management	4.43
Land	4.42
Corn: Production	4.35
Wheat: Production	4.32

A followup study of the results of the Kansas City Conference was made by a work group, which examined the top 10 percent (101) of the total of 1,011 problems considered in the 89 research need areas. Additionally, the work group examined 33 of approximately 65 areas of emphasis from the BARR Report [8]. The summary of the findings of the work group is shown in attachment XI, which shows the estimated base level of effort and recommended increase for each of 33 research need areas. The total increase recommended for these 33 areas of need was 34 percent. The "top 10" research need areas from attachment XI, based on amount of recommended increase in number of scientists, are as follows: [15]

Research Need Areas	Estimated Current SY	Recommended Increase SY
General livestock problems	794	270
Basic problems in plant growth and reproduction	461	180
Energy	177	169
Forage and Range	423	126
Water	339	114
Nutrient requirements	146	112
Soybeans: Production	184	88
Crop protection	602	80
Vegetable crops: Production	418	80
Land	476	80

The report of the followup work group to the Kansas City Conference found evidence that the total current food and food-related research is strongly oriented toward the higher priority areas rated by "user" delegates at the Conference. More than 50 percent of these resources are being used on the top one-fourth of the priority areas while nearly 80 percent are allocated to the top one-half. [15]

Basic Research

Throughout the reports reviewed, there is a general concern that we are not devoting enough effort to basic research [1, 3, 5, 7, 8, 10, 11, 12, 14, 15, 16, 17, 19, 21, 23, 30, 34, 42]. There is a corollary conviction that major breakthroughs in basic research are necessary to provide for the essential increases in crop production which will be needed to provide for the food needs of the world in the decades beyond 1985.

Addeke H. Boerma, former Director-General of FAO, has said in connection with the need for more basic research: [42]

> ...while...the application or adaptation of known scientific principles ...will permit the developing countries to make faster progress toward their nutritional, social, and economic goals during the next two decades, it is clear that more and more countries with high populations and limited natural resources will be pressing the limits of yield and intensification by the end of the century. There is thus an urgent need for more basic research to open up new technical horizons for agriculture in the

> developing countries. Such work may have to be done largely in the developed countries; and I would plead for a planned allocation of their scientific resources to this end.

Sylvan Wittwer has said: [12]

> ...the grossest of omissions in the agricultural research efforts of the Nation...relates to the two most important biochemical processes on Earth, photosynthetic carbon dioxide fixation by the green plant with the bioconversion of solar energy, and biological nitrogen fixation.

Other authorities agree that nonconventional breeding programs, sometimes referred to as genetic "engineering," should be added to these two areas of basic research.

The Office of Technology Assessment (OTA) states: [7]

> ...there is a high probability that expanded research on photosynthesis, nitrogen fixation, and genetic engineering will result in significant payoffs in terms of increased food production.

P. H. Abelson emphasized basic research and states: [36]

> Currently only about 1 percent of the solar energy falling on an area is fixed by photosynthesis. Basic biological research may lead to better efficiencies. This may come about through genetics. One path is the creation of new species of plants by transfer of DNA.
>
> In a time of shortages of energy, improvement of nitrogen fixation by plants is also desirable. Efforts to make more effective use of solar energy have relevance that goes beyond food, for ultimately the world must come to depend largely on renewable resources to fill its many needs. Products derived from plants could supplant most of the petrochemicals currently employed. Energy derived from photosynthesis would be relatively pollution-free. Use of the carbon cycle would also eliminate excessive production of $CO2$.

The BARR Report [8] estimates that about $10 million is being spent for research on photosynthesis with NSF providing $4 million, NIH providing $1 million, AEC-ERDA providing $2 million, and the SAES providing $3 million. The work is widely dispersed among 75 to 100 Federal, university, and industrial laboratories throughout the nation. This same report urges development of: [8]

> ...two or three federally-funded, university affiliated national institutes, with a central theme of research on photosynthesis...

and also urges additional funding of NSF, NIH, AEC-ERDA, and SAES and the development of "...a competitive USDA grant program..." to finance additional research on photosynthesis.

OTA estimates that the USDA-SAES complex is conducting research on photosynthesis at about the $6 million level but recognizes that some of the funds

may be provided by NSF. OTA suggests that funding be through a competitive grant program to scientists who have already demonstrated capability and personal commitment in this field and to institutions which have supported this commitment by allocation of institutional funds. [7]

Other reports suggest additional financial and scientific support or identify specific research approaches to photosynthesis without going into detail as to the best means of concentrating research effort in this area.

The current level of funding of research on biological nitrogen fixation, is estimated in the BARR Report at less than $5 million [8]. This report urges the development of multidisciplinary teams of scientists to study the various approaches to increasing nitrogen fixation. It also recommends the establishment of a technology center to "...acquire, evaluate, and monitor the quality of inoculants sold to farmers..." in connection with rhizobial-based fixation of nitrogen. Other reports identify specific research approaches and recommend additional financial and scientific support for biological nitrogen fixation, with considerable variations in the way the problem is approached.

Genetic engineering is a term used in a few of the reports to cover nonconventional plant breeding. It includes tissue and cell culture and DNA recombination. At present it is estimated that perhaps $500 thousand is being "invested in such non-conventional plant breeding in the U.S." [8]

The OTA report recommends four containment facilities for recombinant DNA research by FY 1981 [7]. Other reports recognize the importance of this area of research and make specific recommendations for expanded financial and scientific support and identify likely approaches to the research problems in this area.

One report emphasizes the importance of linking laboratory research with field research. [7]

Basic problems in plant growth and reproduction ranked high in the order of rating by delegates at the Kansas City Conference. [9]

Basic research was emphasized in the followup work group to the Kansas City Conference. Special emphasis was given to basic problems in plant growth and reproduction including photosynthesis, nitrogen fixation, plant breeding methods, cell studies, plant growth regulators, maintaining propagated germplasm, use of seasonal potential, micronutrient elements, protein quality and quantity, and nutrient availability. Basic research would be done in other areas on a need basis. [15]

Other areas of basic research are emphasized in some of the reports but there seems to be a consensus that photosynthesis, biological fixation of nitrogen, and nonconventional breeding research offer the greatest opportunities at this time.

Since scientists with training and skills outside of the traditionally agricultural disciplines can make significant contributions in these basic research areas, means should be identified for encouraging and supporting their participation in such research.

Research to Protect the Environment and Assure Food Safety

There is a great deal of concern that the need to continually increase our level of nonproduction-oriented or "defensive"1/ research will jeopardize our ability to maintain the level of productivity-increasing research necessary to meet expanding U.S. and world needs for food. The research about which there is concern is that required to enable farmers and other agricultural producers and those engaged in processing, storage, transportation and marketing of food, and other agricultural products to meet stringent new environment controls. There is much apprehension that, without adequate research to develop new or improved practices, procedures, processes, and products our supply of food and fiber may be seriously curtailed at a time when both U.S. and world demand is increasing. R. J. Aldrich has said: [12]

> ...we are concerned that funds for agricultural research are having to be reallocated to an ever-increasing amount from productive to...defensive research. This, among other reasons, is in response to a growing number of government laws and regulations adopted to enhance environmental quality and assure human safety and which additionally seek to regulate fundamental agriculture activities, that is, the use of land, water, labor, equipment, chemicals, and plant varieties. These factors are cited to show that a higher and higher percentage of the U.S. agricultural research funds, the total dollars that are available, including those of industry, are being drained away from research designed to increase and improve the supply of agricultural products.

Dr. Adolph Clausi, Vice-President and Director of Research for General Foods, confirms this view and indicates that the food industry is pessimistic about new developments in food processing because of the need to divert research dollars away from basic research and new product development in order to meet government-imposed requirements for additional, and what he considers excessive, testing for safety, toxicology, and quality controls. Dr. Clausi feels that the Delaney Amendment, in particular, should be reviewed. [12]

A recent survey of leaders in the food industry, as reported by Dr. Karl F. Mattil of Texas A&M University suggests: [12]

> ...that while their expenditures in research and development may increase over the next decade, the great preponderance of their expenditures will be for defensive purposes...
>
> ...it is expected that the food industry will probably...diminish the share of its funds it will contribute to basic food science and engineering. This puts an added responsibility on the food scientists and engineers in government and university laboratories.

1/"Defensive" research is a term used in a number of reports cited to describe current trends in industry and publicly supported laboratories to do research that is "protective" of current products, processes and practices rather than in search of new production or efficiency oriented technology.

Senator Symington, responding to Dr. Clausi's statement, emphasized that regulations were imposed: [12]

> ...to cope with what many scientists and philosophers felt was an inadequate awareness of the finite limits of our resources on this planet and an ability to deal with them in a constructive and safe fashion.

In a somewhat different context, Addeke H. Boerma, former Director-General of FAO, has emphasized the need for "yield-saving" research as being: [42]

> ...more in line with the needs of the developing countries than is the western-based, high-input approach. It could also prove less pollutant.

Much of the research Boerma refers to as "yield-saving" would fit under the broad category of "defensive" research, particularly that related to pollution control and integrated pest and disease control.

The tables in attachments VII and VIII indicate that environmental improvement as a Departmental goal has received the largest percent increase in funding during the period 1966-75.

There is no quarrel with the need for "defensive" research. In fact, it may be long overdue. There is, however, a need to develop a more comprehensive total research program which balances the requirements for "defensive" research with those of the other segments of the research programs.

At present, much of the so-called "defensive" research is primarily a reaction to limitations which have been either proposed or actually placed in operation. The University of California Food Task Force in connection with pollution-related "defensive" research points out that: [4]

> The pervasive nature of pollution and its disregard for political boundaries require broad scale and coordinated environmental quality policies based on sound scientific data. Research is indispensable in the process of (1) developing recommendations to prevent unacceptable environmental deterioration, (2) developing techniques for managing, and in some cases, utilizing pollutants; and (3) specifying the trade-offs between environmental issues--including socio-economic, cultural, legal, and political factors--and production goals.

Human Nutrition Research

Although there are wide differences between the needs of developing countries and the U.S., the University of California Food Task Force has effectively summarized the total human nutrition problem in these words: [4]

> Current knowledge of nutritional requirements is more complete for poultry, cattle, sheep, and pigs than for humans. Human nutritional research should focus on problems of energy (calories) and protein requirements for different sexes, sizes, ages, and activity levels in different climates; the relative values of carbohydrates and fats as energy sources, and the relationship of quantities consumed to human

> health, metabolic individuality of different peoples; development of clinical indices of nutritional status, particularly for children, and the interrelationship among poverty, malnutrition, and disease.

The report of the Kansas City Conference further emphasizes the need for more human nutrition research by stating: [9]

> Our knowledge of the precise kinds, quantities, and balance of nutrients required to achieve optimum human health and productivity is seriously incomplete. Precise knowledge of such requirements (minimal, optimal, excessive intake) is not only incomplete for persons living in an ideal environment but it is particularly so for persons subject to dietary, climatic, or infectious stress. In meeting U.S. and world needs for food, such knowledge is as crucial as measures to increase food production.

In developing countries: [2]

> The foremost problems for improved nutrition are how to provide adequate calories and proteins.

However, there are other nutritional problems which are especially acute in lesser developed countries including: [11a]

> ...such existing severe and acute public health nutritional problems as vitamin A deficiency (causing blindness), iron and folic acid deficiency (causing anemia), (and) iodine deficiency (causing goiter).

The National Academy of Science report goes on to say: [11a]

> The United States is itself scarcely a model for the development of national nutrition policies and programs. Inadequacies are apparent in its funding for research related to health, productivity, learning and behavioral consequences of malnutrition in low-income groups, on the causes and distribution of malnutrition, and on the nutritional impact of U.S. food stamp, school feeding, and other interventions. Moreover, we have shown a reluctance to develop a clearly defined national nutrition policy.

Both USDA and HEW traditionally have "held responsibility for the confusingly divided basis of the nutrition problem." [11a]

One report suggests that: [15]

> Special emphasis in the future should be given to (nutrition research) using human subjects and to reducing current (laboratory nutrition research) work that has little relevance to problems of humans.

Another report states that: [17]

> Nutrition research, and the subsequent education of the public on all aspects of human nutrition, is at a primitive level.

Many of the reports reviewed go into considerable detail as to the type of research considered most urgent or most promising, with most of the proposed research falling into one or another of the broad categories already identified. Infants, growing children, lactating mothers, and the aged are among the most vulnerable groups. [9, 15, 36]

There are mixed feelings about nonconventional and novel sources of protein, such as yeast, bacteria, fungi, green leaf extracts, and chemical synthesis. These sources of protein offer more opportunity for development and acceptance in the long-range than in the next decade or two.

The MIT report identifies a number of constraints to protein production, including energy shortages and costs, legal and regulatory barriers including USDA and FDA standards and procedures, political and institutional constraints to introduction and commercialization of new protein foods, and problems related to marketing of new food products. [23]

The Kansas City Conference gave high priority attention to nutrient requirements, rating this topic fifth among 89 research need areas. Special emphasis was given to (1) requirements by age, sex, occupation, and high risk groups, (2) criteria for establishing nutrient requirements, and (3) interrelationship of nutrients and other food components. [9]

The followup work group to the Kansas City Conference stressed nutrient requirements, nutrient composition, and nutrition education research. [15]

Pest Control Research

Some of the greatest losses, both in food production and in food storage and shipment, are those associated with pests. Weeds compete with growing crops for available moisture, nutrients, and sunlight. Insects damage or destroy plants or plant products both as the plant grows and after it is harvested. Animal productivity and/or growth is limited by insects. Rodents and/or insects destroy much food which is vitally needed to meet total world needs. In addition, insects serve as vectors of diseases that afflict plants, livestock, fish, and humans.

The amount of loss is difficult to determine, but the National Academy of Sciences states that: [8]

> One-third of the annual harvest is destroyed by pests, and substantial losses due to pests during storage further reduce the productivity of U.S. agriculture.

This same report recommends that attention, [8]

> ...be focused on the development of research programs on (1) biologically based hormone or pheromone analogues that interfere selectively with the reproductive processes of the pest species; (2) microbial and natural biological agents for pest control, especially the bacculoviruses; and (3) integrated approaches to pest management, embodying ecologically based strategies based on combinations of the above methods with cultural, genetic, and conventional chemical techniques.

In another, four-volume, NAS study, "Pest Control: An Assessment of Present and Alternative Technologies," much more detail is provided about specific research approaches, but these fall within the broad categories listed above. Recommendations are also made with regard to policies and specific actions which go beyond research, but which are likely to affect the development and emphasis of research programs related to pest management. [34]

The BARR Report contains recommendations which fit into the above categories and in addition proposes that: [8]

> Interdisciplinary teams should be developed of crop protection, plant and animal scientists to set-up crop and livestock production systems which include integrated pest management.

The report of an International Conference sponsored by Michigan State University gives a detailed outline of recommended specific research on plant protection from pests which, in addition to those which fall into the broad categories already listed, includes a proposal to use remote sensing for control operations against migratory pests. [10]

Insect and pest control research was emphasized in the reports of the Kansas City Conference and the followup work group in such areas as pest management systems, biological control, and breeding for resistance in selected crops. [9, 15]

Other reports also make specific recommendations for increased scientific and financial support of research on pest control; and in a number of cases, specify research approaches which need such additional support.

Energy Research

The Arab oil embargo of 1973, and the subsequent sharp increases in oil prices, have had and will continue to have serious impacts on food prices and world trade. Further complicating the agricultural picture has been the developing shortage of natural gas; the increases in costs of manufacturing fertilizer, which is highly dependent on natural gas; and the increased costs of agricultural chemicals.

The effect of increased costs of petroleum, fertilizer, and food will affect everyone; but the most serious impact will be on those developing countries which import all three. The University of California Food Task Force has estimated that about 40 countries with a total population of about 900 million will be particularly hard hit. [4]

The crops in these developing countries which will be hardest hit will be the "...newly developed high-yielding crops requiring chemical fertilizers and pesticides." [4]

Domestically, our high production agriculture is heavily dependent on energy. It is estimated that crop and livestock production requires about 3 percent of our total national energy use and that the entire:

> ...U.S. food system (production, processing, distribution, preparation) uses 12 to 15 percent of the total energy consumed nationally. [8]

It is not surprising that the BARR Report recommends an evaluation of alternative technologies to reduce the energy used in producing, assembling, distributing, and utilizing foods and feeds. Specific research on determining energy flows, developing "effective and economical substitutes for commercial nitrogen fertilizers" and on conservation of energy is recommended. [8]

The Michigan State University Conference takes a slightly different approach and recommends research to:

> ...determine the most efficient balance between nonrenewable energy and human labor in relation to increased food supply. [10]

Basic research on biological fixation of nitrogen and on increasing the photosynthetic conversion of solar energy, which were discussed in an earlier section of this report, are essential to any comprehensive program of research related to energy. Other recommended research includes: "...the use of agricultural wastes and other sources of biomass for producing power and heat." [15], the development of solar, wind, and geothermal sources, recycling wastes, and development of farming systems requiring less energy.

The National Task Force on Agricultural Energy Research and Development categorized energy R&D into three main groupings: [18]

> (1) Conservation and use of energy in production, processing, marketing, and consumption of crops, livestock, and forest products (2) Substitution by renewable or non-critical energy sources and forms which include use of biomass for energy production; use of solar, wind, and geothermal energy; use of coal, lignite, oil shale, peat, and electricity; use of waste heat from power plants and other sources (3) Physical and socioeconomic consequences which deal with alternatives for energy production, availability, and use including the impact on natural resources and the environment.

This same report provides additional technical and organization policies, goals, and recommendations for implementation.

The Kansas City Conference gave top priority to energy research [9]. The followup work group stressed the need for research on (1) nitrogen sources, (2) use of wastes, (3) recycling of wastes, (4) use of solar energy, (5) equipment performance, and (6) energy conservation practices. [15]

A five-part energy policy for the food system has been proposed by a panel of experts on food and safety: [52]

1. Energy conservation must be developed and practiced in the food system.

2. Fuels which are plentiful and renewable must be substituted for fuels in short supply.

3. Alternative energy sources that originate from or are especially suited to the food system must be developed and used.

4. Sectors of the food system must be assigned priority use of petroleum where no other fuel is available for operation of heavy duty mobile work vehicles.

5. Sectors of the food system must be assigned priority use of natural or synthetic gas for those operations in which no substitute fuel has been developed.

Other reports recognize the importance of the energy crisis as it affects agriculture, both domestically and in the developing countries, and provide recommendations which would fall into one or another of the various categories previously discussed. There is general agreement that the full impact has not yet been felt; and that there is an urgent need for additional research in this area.

Production Efficiency Research

Throughout the reports reviewed, there is general agreement on the need for increased crop and animal production and on the need for research required simply to meet the requirements of U.S. population growth; the U.S. will need one-third more food by the year 2000 [12]. This, of course, will require additional productivity in the entire range of agricultural food crops. Present trends indicate that in the U.S., the demand for horticultural and meat products will increase more rapidly than for food grains.

However, to meet world food requirements, the University of California Food Task Force has said: [4]

> The outlook for future world food production depends to a substantial degree on what happens to seven major crops: wheat, rice, maize, soybeans, sugar, potatoes, and pulses.

There will be need for a broad range of increased crop research activities if we are to meet both U.S. and world food requirements. Some aspects of basic plant research and the need for more effective insect and pest control have already been cited. In addition, the following recommendations have been made in the various reports reviewed: (1) Strengthen research support for the basic plant sciences [10]; (2) intensify and expand international efforts to preserve, conserve, and exchange genetic resources [10]; (3) broaden the range of parameters in plant breeding research [10]; (4) develop more efficient methods of crop fertilization [12]; (5) accelerate work on conventional breeding for higher and more dependable yields [11]; (6) develop a variety of intensive cropping systems for the tropics [11]; and (7) increase the protein value of grain. Recommendations for expanded crops research in the other reports reviewed fit into one or another of the categories cited.

The Kansas City Conference and the followup study group gave high priority to soybean, corn, wheat, dairy, beef, vegetable crop, and aquatic food production and production systems. [9, 15]

It is not likely that in the near future the U.S. will become a major exporter of meat or meat products, since we presently import a portion of our needs. There is need for an expanded livestock industry in the U.S. and in some of the developing countries to effectively utilize the forage which represents the most effective use of particular soils and climates. Serious problems face the developing countries in more effectively exploiting their livestock-forage capabilities. According to the Interim Report of the National Academy of Sciences: [11]

> The central production problem in developing countries is low yield of the animal products, primarily meat and milk, rather than insufficient numbers....the principal limiting factors are feed, diseases, low reproductive efficiency, and inadequate access to markets...The highest immediate research priority is improvement and management of forages for the predominant rangeland ecosystems around the world.

The same report goes on to say: [11]

> Thus far, the U.S. has confronted tropical livestock diseases only as a potential invading host that threatens to contaminate our animals and food supply...This approach will be increasingly unsatisfactory. It stifles imports of low cost animal products, which should be an important component of expanding two-way food trade between the U.S. and developing countries. It also inhibits international exchange of new animal germplasm.

Specific livestock research areas identified as having significant potential for increased production both in the U.S. and in the developing countries include: (1) control of reproductive diseases, (2) increasing the number and controlling the sex of progeny, (3) developing genetically superior animals, (4) improving food conversion efficiency, (5) more effective control of major diseases which affect animal productivity, and (6) development of practices to permit earlier weaning.

Policy decisions involving the future of livestock and poultry production must take into account the long-term nature of most areas of farm animal research; the apparent need for more fundamental research to better understand physiological and biochemical processes; and the existence of a number of technological and/or biological barriers including reproductive efficiency, feed conversion efficiency, and egg laying rate in poultry. Also, greater emphasis may be needed on livestock-forage-range production systems, given the likelihood that in the long run animal production will trend toward greater use of forages and/or alternatives to feed grains and protein rich oilseed crops.

Processing, Storage, Distribution, and Delivery Systems Research

With the possible exception of production losses, those losses associated with the processing, storage, distribution, and delivery of agricultural food products are perhaps the most serious in the entire food production to consumption chain. The problem is especially serious in the developing countries where facilities are less adequate and opportunities for losses to develop are more numerous. The University of California Food Task Force, in discussing losses in developing countries, maintains that: [4]

> Food processing losses are even more serious than losses in production because of energy and other resources expended.

Another study indicates that:

> In many countries, post-harvest losses of certain food crops, if held long in storage, may reach 50 percent.

In the developing countries: [11a]

> Distribution systems frequently are so limited that areas of famine exist close by regions of abundance.

The post-harvest food loss problems in the U.S. and developing countries are similar, even though they may differ widely in degree. In both instances, it is essential to move crops and animal products promptly from the point of harvest or slaughter to the point where they enter processing or consumption channels. Effective transportation, refrigerated if necessary, providing protection against losses by predators, decay or disease organisms, and physical damage is essential.

The BARR Report [8], largely addressing domestic issues, suggests that major emphasis be placed on research leading to:

> (1) Reducing losses of raw product, (2) Reducing losses of prepared product, (3) Improved standardization of packaging system, and (4) Development of a more detailed national transportation plan as it affects agriculture.

The Kansas City Conference identified food technology (with emphasis on low-energy systems, cost of sanitation, food wastes, cost of delivery and water requirements in processing), food safety (emphasis on ways to detect, handle, and avoid contaminants, chemical and physical methods of detoxifying mycotoxins, and methods for testing, detecting, and controlling natural toxicants), and education research for food delivery systems. [9]

The followup work group to the Kansas City Conference stressed the importance of food technology, food safety, and delivery systems and recommended increases of 143 scientists on these need areas. [15]

In a somewhat different context, that of reducing energy requirements, another report recommends the development of

> ...alternative methods of delivery to reduce transportation and storage requirements with special emphasis to reduce refrigeration needs.

This particular recommendation, though designed for U.S. conditions, would have particular relevance to developing countries. Recommendations in other reports fall within the categories already described.

Increased food production, particularly in the developing countries, depends heavily on wise use of our soil and water resources. As the University of California Food Task Force has pointed out: [4]

> Methods must be found for bringing under cultivation new land that until now has not been economically feasible because of extremely low fertility, high acidity, and unfavorable water relations.

These soils are found largely in the tropics and are usually either not cultivated or are cultivated intermittently because of their rapid decline in productivity. In such areas, climate is likely to be favorable for crop growth; and water is generally not limiting. In other, more arid, areas, water is the limiting factor.

Problems of salinity, waterlogging, and water quality are dominant in irrigated areas. Problems associated with salinity of land plague both developed and developing countries. Despite high costs and energy consumption, falling ground water levels, and overappropriation of surface waters, irrigation will play a major role in crop production worldwide. This is shown by the fact that about one-fourth of the total gross farm receipts in the U.S. come from the 10 percent of the land that is irrigated. Also, without irrigation, much of this land would not produce appreciable food. Similarly, there is great need for improved water use efficiency in rain-fed areas as shown by the statement: [8]

> For the world as a whole, (water) is a limiting factor in food production on more than 1.4 billion hectares of nonirrigated land.

We have no effective inventory of our total water resources either in the U.S. or in the developing countries.

Erosion continues to be a major problem, even in the U.S., removing soil at a rate approximately 8-fold greater than the average rate of soil formation, and costing approximately $500 million annually.

> Clearly, the United States cannot afford to degrade and eliminate from production another several million acres of cropland as it did in the past ...the erosion problem will intensify as the demand for food increases.1/

As late as 1965, nearly two-thirds of the nonfederal land in the U.S., which has the best soil resources of any country, still needed some kind of conservation practices.2/

1/Pimentel, D., et al. Land Degradation: Effects on Food and Energy Resources. Science 194:149-155. 1976.

2/Soil and Water Conservation Needs-A National Inventory. USDA Misc. Publ. No. 971. 1965.

We have only a partial inventory of land resources in the U.S. and essentially none in the developing countries.

> Estimates of the reserve land resources for crop production in the U.S. alone vary from 20 to 60 million hectares. [8]

Water and land ranked third and eighth, respectively, among 89 research need areas considered by the Kansas City Conference. Emphasis on water research was given to water policies and laws, quality, and conservation and use. Research needs applicable to lands were on resource appraisal and allocation, management and fertility, erosion, and pollution [9]. The followup work group recommends support for these areas be increased by 194 scientists. [15]

Specific recommendations with regard to land and water resource use and conservation are included in several of the reports, but they generally fall within the categories identified in the BARR Report [8]. These include (1) soil resources inventory, (2) interpretation and use of soil resource data, (3) soil fertility evaluation, (4) conservation of soil resources, (5) farming low precipitation areas for maximum production, (6) use and management of rangelands, (7) cropping systems to make most effective use of water, (8) soil-water management systems (9) technology and management for water supplies, and (10) constraints on water management.

Demands on land and water resources grow apace with population--

> Decisionmakers, especially public ones, are under more pressure to make enlightened decisions on the use of land. But our ability to identify and evaluate land use alternatives remains inadequate. This is particularly crucial when we recognize that land use decisions have a high degree of permanence, and in many cases, may be irreversible. It is in this context that the agricultural research community must pay more attention to land use problems by providing research results to facilitate informed decisionmaking.1/

> Water management is a complex problem. The general public and, in some cases, even the personnel of planning and regulatory agencies, do not realize how many intricate pieces must be fitted together if a properly integrated and coherent water management program is to be achieved which will properly deal with our whole ecosystem. This whole area of water and environment is full of tremendous challenges to agronomists, other professionals, and to clear-thinking opinionshapers and decision-makers.2/

1/Land Use - Issues and Research Needs for Planning, Policy, and Allocation. NPC-ARPAC. Feb. 1976.

2/Robert M. Hagin. Water Management: Some Effects of New Societal Attitudes. In Agronomic Research for Food. Amer. Soc. Agronomy Spec. Publ. No. 26. 1976.

Natural and Renewable Resources Research - Forestry

Forests represent a renewable resource that can be applied to meet many of today's problems. The materials available from forests can be used for "...housing and other structural purposes, paper and paperboard, textiles, chemical feedstocks and fuel..." [21]. In many cases, forest products can be used in substitution for, or to augment, scarce or costly nonrenewable resources. There is particular need for research to increase the materials supply from existing forests and to increase our knowledge of wood science and technology. More specifically, the national forest survey should be enlarged to provide additional and more useful data, the socio-economic aspects of forestry should be studied; the opportunities to increase materials supply through intensive forest management should be evaluated; the energy requirements of timber production and the opportunities to decrease the dependence of these activities on external energy supplies should be evaluated; creation and maintenance of university centers of research in renewable materials should be encouraged; early applications of new technology in the production of renewable materials should be encouraged; private forestry corporations should be encouraged to participate with public research organizations in cooperative research designed to produce published results; the responsibility for policy issues of science and technology in the field of renewable resources should be established under the Office of Science and Technology Policy; the influence of institutional barriers on the balance of trade in wood, both internally and externally, should be evaluated; studies should be initiated to develop improved processes for manufacturing structural materials from wood flakes, strands, veneer, fiber and other wood products or by-products; and, in general, studies should be made of more effective use of forest products for various chemical and energy purposes.

Weather and Climate

Research on weather and climate could have a significant effect on improving plant and animal production either in the U.S. or in the developing countries or both. Changed patterns of rainfall and snowfall in the past few years have led to unprecedented drought conditions in parts of Western Europe, China, and the U.S. In other parts of the U.S., there has been excessive precipitation with delayed planting and/or poor growing or harvesting conditions. Research is particularly needed (1) to develop more effective weather predictive capability, particularly longer range predictions, so that farmers can plan their season's activities and choice of crops more effectively, (2) to provide, through weather modification procedures, more adequate amounts and distribution of rainfall for better growing conditions and greater productivity, (3) to limit damage from hail by improved hail suppression techniques, (4) to limit other crop and animal losses associated with, or exacerbated by, specific weather conditions through integrated programs of better predictive capability; modification of weather, climate and/or microclimate; and development of procedures, practices, and varieties more adaptable to particular weather conditions.

The legislative authority of USDA to participate in some of this research is not clear. However, USDA and the State Agricultural Experiment Stations

have expertise in related areas such as remote sensing, agricultural meteorology and climatology, and relationship of climate and stress variables to crop yields and quality.

Fluctuations in weather and climate are a major cause of variation in food and fiber production from one season to another. Weather and climate ranked 31st among 89 research need areas at the Kansas City Conference where emphasis was given to resource appraisal, climatic stress, and weather modification [9]. The followup work group stressed area evaluation, weather information, impact studies, and weather modification. The work group recommended increases of 45 scientists in support of these areas and noted a relatively small base level of current effort. [15]

Aquaculture

Aquaculture, the cultivation of fish species, offers an opportunity to increase food production through effective use of manmade or naturally occurring ponds. These ponds can be used to produce a high-protein food crop on areas which might otherwise be nonproductive. In some cases, culture of fish and shellfish is, or can be, integrated into more traditional production systems such as rice production. The legislative authority of the USDA to participate in research related to aquaculture is vague. There is a possibility of overlapping or conflicting authorities between USDA and Interior's Bureau of Sport Fisheries and/or Commerce's Bureau of Commercial Fisheries. As a result, USDA is not conducting research on aquaculture.

The State Agricultural Experiment Stations, operating under somewhat broader authority, are conducting a limited program of research in this area.

Production of aquatic food sources ranked 15th among 89 research need areas at the Kansas City Conference. Marketing and processing of aquatic food sources ranked 36th [9]. The followup work group identified wild stocks and aquaculture as areas of research need. [15]

Research in aquaculture is needed in developing fish culture and management techniques to maximize yields, in breeding and selection, in nutrition, and in disease control.

Labor Intensive Research for U.S. and Developing Countries

The problem of world food supply, and the means by which the developing countries increase the productivity of their agricultural systems to meet their food requirements, is incidental to the scope of this report. To do justice to these complex problems would require a separate study and report at least comparable in scope to this report. However, a few observations are in order. It is generally agreed that the bulk of the increase in food supply for the developing countries must come from increased production in those countries. Except for some of the less densely populated areas of Latin America and Africa, the increases must come from intensified agriculture and the use of improved methods to increase annual yields on land already under cultivation. It is also generally recognized that: "The products of technology and 'know-how' cannot be transferred directly to the developing nations." [2]

Research in direct or indirect support of developing countries and international food and agricultural systems was identified as being very important at the Kansas City Conference. Emphasis was given to (1) food production technology and resource management (high-yielding varieties of selected food legumes and vegetables; high-yielding varieties of cereals; soil and water management technology; biological nitrogen fixation; high-yielding varieties of selected starch foods; and low-energy technology food production and use systems), which ranked 7th; (2) U.S. public policy on world food reserves, foreign assistance and trade, which ranked 16th, (3) food quality and distribution in support of developing countries, which ranked 23rd, and (4) research to develop economic, political and institutional arrangements for international development, which ranked 33rd among 89 research need areas [9]. The followup work group examined these and stressed research needs for food legumes, starch food staples, and plant nutrients. [15]

Present legislation and/or administrative policy generally restricts USDA research agencies to research directly affecting U.S. agriculture. Similarly, the Hatch Act, which provides Federal grant funds to the SAES, has been interpreted as limiting the use of these funds to research directly benefiting U.S. agriculture. By implication, if not by regulation, the restrictions of the Hatch Act have been extended to other Federal grant funds administered through the Cooperative State Research Service.

Exceptions to these general restrictions are the Special Foreign Currency Research program under PL-480 and the Tropical and Sub-Tropical Agricultural Research program under Section 406 of the Food for Peace Act of 1954. Under the PL-480 program, research is being conducted by ARS only in the few countries which meet the excess currency requirements of the law.

Under section 406, research to date has been limited to the U.S. and Puerto Rico, although the wording of the act apparently would not preclude research in friendly tropical or subtropical nations. Presumably, this act could provide the basis for direct research participation with some of the international agricultural research and development organizations associated with the Consultive Group for International Agricultural Research, as well as for other cooperative research in tropical or subtropical developing countries.

Also, there is renewed interest in the U.S. in the problems of small farms and home gardeners. Some of the work in this area, which is largely labor-intensive and in some cases essentially subsistence farming, could be of direct value to developing countries having similar climates and soils. Social, economic, political, and educational constraints to technology transfer are serious and continuing and require research.

Problems of overlapping or conflicting responsibility between AID and USDA appear to be obstacles to both adequate funding and more effective participation of USDA in providing research to meet the needs of developing countries. Title XII of the International Development Food Assistance Act of 1975 offers promise for bringing the research capabilities of U.S. universities to bear on the research needs of the developing countries.

Policy Analysis and Monitoring of System Performance

Organization of resources to provide food received higher than average priority at the Kansas City Conference. All 11 of the research need areas in this category were ranked by the delegates in the top half of the list. Several of these are covered in earlier sections of this report, especially for production and marketing systems and production inputs and services.

Other research needs for policy analysis and monitoring of food production performance which were stressed by the Kansas City Conference included domestic public policy, which ranked 13th; international public policy, 16th; finance, 28th; human resources, 30th; and social institutions, 42nd out of 89 need areas. The followup work group to the Kansas City Conference recommended increases for the first four of the above-mentioned areas. [9, 15]

While social and economic research needs are not given high visibility in the previous sections of this report, they are important components of many of the indicated areas of priority. Special emphasis is needed on social and economic research to monitor the performance of the system from producer to consumer to detect change, to provide an improved input into the research planning process, and to provide analyses of policy affecting all aspects of resource utilization and development for agriculture and rural areas.

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ATTACHMENTS

FUNDING OF FOOD-RELATED RESEARCH, FY 76

(million of dollars)

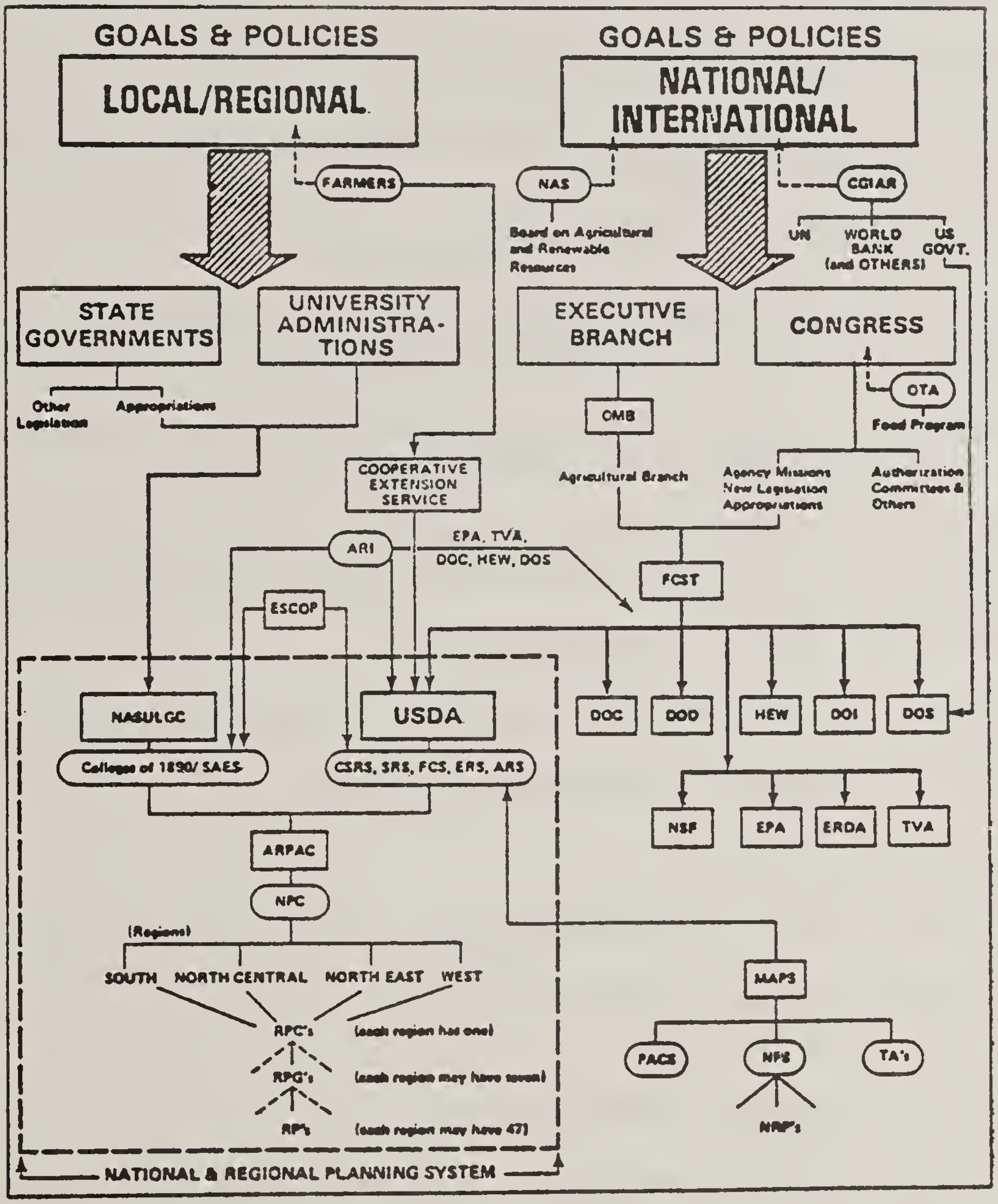
CLASSIFICATION	ORGANIZATION	SUBDIVISION/ PROGRAM/LABORATORY	AMOUNT OF FUNDING	REFERENCE
FEDERAL GOVERNMENT TOTAL: 584.81	Dept. of Agriculture (USDA) TOTAL: 314.99	Agricultural Research Service (ARS)	209.115	1
		Farmer Cooperative Service (FCS)	0.965	2
		Economic Research Service (ERS)	23.334	3
		Statistical Reporting Service (SRS)	0.5	4
		Cooperative State Research Service (CSRS)	81.083	5
	Dept. of Commerce (DOC) TOTAL: 34.99	National Bureau of Standards (NBS)	0.57	6
		National Oceanic & Atmospheric Administration (NOAA) (National Marine Fisheries Service)	34.42	7
	Dept. of State (DOS) TOTAL: 49.218	Agency for International Development (AID)	49.218	8
	Dept. of Interior (DOI) TOTAL: 4.397	U.S. Geological Survey (USGS)	4.397	9
	Dept. of Health, Education & Welfare (HEW) TOTAL: 68.3	National Insitutes of Health (NIH)	53.0	10
		Food & Drug Administration (FDA)	15.3	11
	Energy Research and Development Admin. (ERDA) TOTAL: 43.03	Biomedical and Environment (BER)	39.7	12
		Solar Energy (SE)	3.33	13
	Dept. of Defense (DOD) TOTAL: 15.615	U.S. Army Natick Dev. (NDC) Letterman Army Inst. of Research (LAIR)	15.615	14
	Environmental Protection Agency (EPA) TOTAL: 14.73	Programs		
		Agricultural Pollution Control (APC)	3.894	15
		Alternate Pest Management (APM)	1.5	16
		Health & Ecological Effects (HEE)	6.187	17
		Effects of Pollutants (EP)	2.5	18
		Food Products Industry (FPI)	.65	19
	Tennessee Valley Authority (TVA) TOTAL: 6.0	In-House Programs	6.0	20

CLASSIFICATION	ORGANIZATION	SUBDIVISION/ PROGRAM/LABORATORY	AMOUNT OF FUNDING	REFERENCE
	National Science Foundation (NSF) TOTAL: 33.55	Directorate for Biological, Behavioral, & Social Sciences (BBSS)	27.2	21
		Directorate for Astronomical, Atmospheric, Earth, & Ocean Sciences (AAEO)	.55	22
		RANN	3.6	23
		Directorate for Scientific, Technological & International Affairs (STIA)	2.2	22, 24
NON-PROFIT INSTITUTIONS 35 TOTAL: 15.273	Ford Foundation (FF) TOTAL: 3.553	Foreign, Extra-mural Programs	3.553	25
	Rockefeller Foundation (RF) TOTAL: 7.7	Conquest of Hunger (COH)	7.0	26
		Quality of Environment (QE)	.45	26
		Equal Opportunity (EO)	.25	26
	Kellogg Foundation (KF) TOTAL: 0.370	Foreign Projects	.176	27
		American Indian Projects	.194	27
	C.F. Kettering Foundation (CFK) TOTAL: 1.9	Yellow Springs Laboratory (YSL)	1.65	28
		Extra-mural	.25	28
	Boyce Thompson Institute (BTI) TOTAL: 1.5	Institute for Plant Res. (from endowments) (IPR)	1.5	29
	Mid-West Research Institute (MRI) TOTAL: 0.25	In House Programs	0.25	34

CLASSIFICATION	ORGANIZATION	SUBDIVISION/ PROGRAM/LABORATORY	AMOUNT OF FUNDING	REFERENCE
	Grouped by Interest:			
PRIVATE INDUSTRY	Food Industry (1973 best available information)		268.	30
TOTAL: 393.0	Other Food-Related (Estimate only)		125.	30
STATE GOVERN-MENTS	Appropriations to Non-Land Grant Universities		1.968	40
TOTAL: 230.22	Appropriations to SAES & Colleges of 1890		223.252	31
32 NON-SAES UNIVERSITIES	Nine Universities See 33.		19.32	33
TOTAL: 19.32				
TOTAL FUNDING REPORTED: 1,242.				

Source: Special Oversight Report No. 2. by the Subcommittee on Science, Research, and Technology and the Subcommittee on Domestic and International Scientific Planning and Analysis of the Committee on Science and Technology, U.S. House of Representatives, 94th Congress-2nd Session, August 1976, pages 116-119. (17)

FACTORS/ORGANIZATIONS AFFECTING FOOD-RESEARCH POLICIES IN THE PUBLIC SYSTEM



This chart indicates all of the policy systems, factors, or organizations which could be identified during the hearings as affecting food-research policies in the public system. The National and Regional Agricultural Research Planning System is enclosed by dotted lines.

Source: Special Oversight Report No. 2. by the Subcommittee on Science, Research, and Technology and the Subcommittee on Domestic and International Scientific Planning and Analysis of the Committee on Science and Technology, U.S. House of Representatives, 94th Congress-2nd Session, August 1976, page 43. (17)

Examples of Achievement Through Agricultural Research in the U.S.

- Discovery of Vitamins A, E, K, and B12
- Discovery of the anticoagulant dicumarol. Some estimate that the use of this drug saves the lives of one out of every three persons struck with coronary thrombosis
- Isolation of streptomycin from soil fungi
- Regeneration and silvicultural knowledge necessary to reforest the Northwest and South after exploitive cutting
- Sterile male technique for control of insect pests
- Discovery of the role of RNA in protein synthesis, a discovery that led to a Nobel Prize in 1968 for Dr. Bob Holley in biochemistry and medicine
- Discovery of clinical dextran, a blood plasma substitute now extensively used to restore blood volume lost through injury or shock
- Discovery of Marek's Disease vaccine, considered to be one of the most outstanding developments in the virus-cancer field involving man and animals
- Flame resistance for popular clothing fabrics
- Biological control of insect pests through importation of natural enemies
- Process to permit commercial penicillin production
- Durable-press cotton fabrics
- Process for making frozen concentrated orange juice in the mid-1940's
- Biological "redesign" of the soybean from a minor hay crop to the world's most valued plant protein source
- Laser-beam automatic grading control system
- Discovery of photoperiodism, the fundamental law of nature that many plants flower and produce seed only when day-lengths are favorable
- The aerosol bomb in 1941 developed originally for insecticides but now used widely to package a variety of products
- Control technology for bovine brucellosis, a disease that once caused losses of $100 million annually, plus incalculable misery to humans as undulant fever

- Development and application of reproduction principles in livestock which made artificial insemination of dairy cattle and poultry common practices today

Important Science and Technology Issues

Table 2-6. Important Issues Pertaining to Dependability in Funding for Research

University
There is need for more continuity and stability in government funding of research; research grants should be longer.
More coordination of research at the national level, more consistent policy, and more planning are needed.
More money in general is needed for research; there should be more basic research.
Funds are needed for research equipment, instrumentation, and maintenance.
More support for university research should be supplied at the institutional level.

Industry
Absence of national science and technology policy, priorities or goals.
General economic conditions, particularly inflation in salaries and laboratory costs, lead to decreases in fundamental research in industry.
Lack of availability of money, low profitability or obstacles to capital formation lead to decreases in fundamental research in industry.
Concern over general decrease in fundamental and other research in industry.

Government Laboratories & FFRDC's
Need for coordinated research policy at the national level involving long-range planning, commitments and priorities.
Need for increased or stable funding.

Independent Research Institutes
Need for long-term continuity in funding.
Lack of coherent national science policy especially toward IRI's.
Need for research funds including construction funds.

Table 2-7. Important Issues Pertaining to the Vitality of the Research System

University
Hiring and research support problems are experienced by younger faculty; departments cannot hire because of tenure; older faculty do not leave.
The continued supply of manpower to do research must be insured.
More support is needed for graduate studies.
Increased teaching loads take time away from research.

Industry
Concern about quality of new people—best are not entering science and engineering or, if they do, are kept for university.
Too few/too many scientific and technical personnel—no match with need—lack of national policy on scientific and technical personnel.

Government Laboratories & FFRDC's
Desire for improved personnel management (e.g., personnel changes, salary scales, staff levels, etc.).
Need to maintain research staff vitality with more positions for young scientists and continuing education for older ones.

Independent Research Institutes
Manpower needs—particularly in IRI's—as problems associated with multi-disciplinary efforts.

Table 2-8. Important Issues Pertaining to Freedom in the Research System

University

There is pressure for applied research in preference to basic or pure research; projects are overly "targeted" or their subjects too minutely defined.

There are excessive demands for accountability in the use of funds provided by government.

Industry

Government regulations and controls (unreasonable, not thought out, no cost/benefit/risk analysis).

Near-term relevance is only research objective (due to government regulations or decentralization of research to profit centers).

Deteriorating patent protection or patent policy is a disincentive to industrial research and innovation.

Competing R&D functions (e.g., applied research or development in response to government regulations) decrease fundamental research in industry.

Government Laboratories & FFRDC's

Increased emphasis on short-term research and neglect of basic research.

Overmanagement as evidenced by too many restrictions especially on longer-term research.

Independent Research Institutes

Federal pressure toward over-direction of research with emphasis on short-term or applied research.

Table 2-9. Important Issues Pertaining to Confidence in Science and Technology

University

The public has a negative attitude toward science and technology.

Government (State, local, or Federal) or one of its branches or agencies has a negative attitude toward science and technology.

A program of education or communication is needed to convince the public and government of the value of research.

Industry

Low public confidence in and/or poor image of science, technology, research or scientists.

Government Laboratories & FFRDC's

Meeting public demand for justification of basic research programs with respect to mission.

Lack of Congressional or Executive support and understanding of basic research.

Independent Research Institutes

Need for adequate justification of research.

Source: Science at the Bicentennial, A Report from the Research Community, Report of the National Science Board/1976, by the National Science Board, National Science Foundation, 1976, pages 28-30. (39)

Recommendations by the Special Oversight Review of Agricultural Research and Development in a Report by the Subcommittee on Science, Research and Technology and the Subcommittee on Domestic and International Scientific Planning and Analysis (Special Oversight Report No. 2) of the Committee on Science and Technology, U.S. House of Representatives, August 1976. (17)

Recommendation 1. A Clearly Defined National Policy for Agricultural Research Should Be Established

Recommendation 2. Individuals Qualified and Knowledgeable in the Agricultural Sciences Should Be Included at the Highest Levels of National Science Policymaking

Recommendation 3. The Leadership Role of the Department of Agriculture in the Conduct and Support of Federally Funded Agricultural Research Programs Should Be Examined

Recommendation 4. Improved Information Exchange Between the Public and Private Sectors in the Field of Agricultural Research Should be Encouraged and New Ways To Improve Such Information Exchange Should Be Explored

Recommendation 5. Competitive Procedures for the Award of Agricultural Research Grants Should Be More Widely Employed

Recommendation 6. "Special Reviews" and "On-Site Reviews" of State Agricultural Experiment Stations, Currently Performed by the Cooperative State Research Service, Should Be Strengthened and More Widely Used

Recommendation 7. Research That is National in Scope or Which Requires Major Capital Investments Should Be Centralized When Appropriate

Recommendation 8. Excellence Among Members of the Agricultural Research Community Should be Given Recognition

Recommendation 9. Increased Levels of Support Should be Provided for Those Areas of Agricultural Research Which Are Needed to Meet Future United States and World Needs

Recommendation 10. Basic Research Programs of the National Science Foundation Which Are Important to Agriculture Should Be Strengthened

Recommendation 11. The Nation's Agricultural Research Effort Should be Better Balanced Between Short-Term, Commodity-Oriented Programs and Long-Term, High-Risk Work

Recommendation 12. There Should Be An On-Going Evaluation of the Scientific Bases Which Govern Food and Agriculture Regulations

<u>Recommendation 13</u>. Interdisciplinary Efforts, Especially Among Scientists and Basic Researchers Outside the Agricultural Research System, Should Be Encouraged

<u>Recommendation 14</u>. The Conclusions and Proceedings of Conferences Relating to Agricultural Research Should be Made Widely Available and Utilized Where Possible

<u>Recommendation 15</u>. Organizations Outside the USDA-State Agricultural Experiment Station System Should be Invited to Participate in Research and Extension Advisory Committees

UNITED STATES DEPARTMENT OF AGRICULTURE

Appropriations for Research
Fiscal Years 1966-1977
($ in Millions)

AGENCY	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Research:												
Agricultural Research Service[a/]	$147.0	$155.4	$152.8	$148.4	$165.1	$188.6	$201.7	$218.1	$210.1	$229.3	$278.9	$273.2
Cooperative State Research Service . .	55.3	58.8	59.0	59.0	62.7	69.7	82.9	91.5	90.1	101.7	114.5	122.5
Statistical Reporting Service.	.4	.4	.4	.4	.4	.6	.7	.5	.9	1.2	2.0	2.0
Economic Research Service.	12.2	12.9	13.3	13.9	15.5	16.6	16.5	18.6	19.7[b/]	22.4	25.8	26.1
Farmer Cooperative Service	.8	.8	.9	.9	1.0	1.1	1.1	1.3	1.4	1.1	1.3	1.3
Forest Service	37.4	38.5	41.2	40.0	45.6	48.8	54.6	57.8	64.7	77.6	80.4	84.7
Total, Research.	$253.1	$266.8	$267.6	$262.6	$290.3	$329.4	$357.5	$387.8	$386.9	$433.3	$502.9	$509.8

a/ Includes Special Foreign Currency Program.

b/ Includes $1,236,000 for the Rural Development Service.

OISTRIBUTION OF RESEARCH FUNOS BY CRIS RESEARCH PROBLEM AREA GOALS - FY 1966 TO 1976[1/]
(MILLIONS OF OOLLARS)[2/]

AGENCY GOAL[3/]	FISCAL YEAR 1966[4/]	1967[5/]	1968	1969	1970	1971	1972	1973	1974	1975	PERCENT CHANGE 1966-1975
ARS											
I NATURAL RESOURCES	17.1	18.5	20.0	19.8	19.9	20.5	21.5	22.0	21.7	23.7	39
II PROTECTION	44.7	46.7	42.8	44.3	43.0	48.1	54.7	53.9	56.2	60.5	35
III PROOUCTION	19.6	20.8	22.6	23.3	30.3	33.2	36.0	39.2	40.9	47.5	142
SUBTOTAL: II + III	64.3	67.5	65.4	67.6	73.3	81.3	90.7	93.1	97.1	108.0	68
IV PROOUCTS, PROCESSES & QUALITY	36.6	39.2	36.0	35.4	36.4	38.0	38.4	39.5	39.2	40.1	10
V MARKETING SYSTEMS	3.0	3.6	4.3	3.9	4.7	4.9	5.0	5.4	5.3	5.4	80
VI EXPORTS & FOREIGN ASSISTANCE	1.0	1.4	.3	1.1	1.4	1.7	1.9	2.0	2.8	2.7	170
VII HUMAN HEALTH & NUTRITION	9.6	9.5	10.8	12.3	14.8	18.1	20.1	21.0	23.4	25.3	164
VIII RURAL LIVING	.4	.4	.4	.5	.6	.6	.5	.4	.5	.6	50
IX ENVIRONMENTAL IMPROVEMENT	4.7	5.7	5.1	5.8	9.0	10.8	14.5	16.0	16.9	18.0	283
OTHER	--	--	.2	.4	1.3	.1	--	1.0	.1	.3	--
SUBTOTAL: ALL OTHER	72.4	78.3	77.1	79.2	88.1	94.7	101.9	107.3	109.9	116.1	60
TOTAL	136.8	145.7	142.4	146.8	161.1	176.1	192.6	200.3	207.0	224.1	64
NATIONAL TOTAL[6/]											
I NATURAL RESOURCES	50.5	53.5	56.2	59.1	63.4	67.9	72.0	75.3	82.2	94.5	87
II PROTECTION	100.9	104.0	102.4	106.1	103.5	113.1	125.8	135.5	150.8	169.7	68
III PROOUCTION	125.6	125.6	138.2	141.0	166.0	178.9	188.3	204.4	224.6	249.9	99
SUBTOTAL: II + III	226.5	229.6	240.6	247.1	269.5	292.0	314.1	339.9	375.4	419.6	85
IV PROOUCTS, PROCESSES & QUALITY	62.6	65.1	56.1	64.4	66.7	70.1	73.2	76.3	81.0	86.3	38
V MARKETING SYSTEMS	8.2	8.8	19.3	19.4	21.0	22.4	23.3	24.2	26.4	29.0	254
VI EXPORTS & FOREIGN ASSISTANCE	3.6	4.5	2.7	3.6	4.1	5.2	5.6	5.3	5.9	6.8	89
VII HUMAN HEALTH & NUTRITION	19.8	20.4	21.5	24.1	26.8	29.5	33.7	37.5	41.4	47.1	138
VIII RURAL LIVING	18.4	18.8	9.2	11.6	11.3	13.5	13.2	14.4	15.3	17.1	- 7
IX ENVIRONMENTAL IMPROVEMENT	22.6	24.9	26.9	30.6	37.5	46.1	56.3	64.4	73.3	83.0	267
OTHER	--	--	32.9	37.3	36.2	36.6	35.7	33.5	28.3	40.2	--
SUBTOTAL: ALL OTHER	185.7	196.0	224.8	250.1	267.0	291.3	313.0	330.9	353.8	404.0	117
TOTAL	412.1	425.6	465.4	497.3	536.6	583.4	627.1	670.7	729.2	823.5	100

[1/] OATA FOR FISCAL YEARS 1966-1975 SUMMARIZEO FROM THE INVENTORY OF AGRICULTURAL RESEARCH FROM THE CURRENT RESEARCH INFORMATION SYSTEM (CRIS).

[2/] SUMS OF INOIVIOUAL ITEMS MAY NOT AGREE WITH COLUMN TOTALS BECAUSE OF ROUNOING.

[3/] SEE PAGES xiv-xvii OF INVENTORY OF AGRICULTURAL RESEARCH, VOL. II, 1975, FOR MORE COMPLETE OESCRIPTION OF GOALS.

[4/] OATA FOR 1966 INCLUOEO IN THE 1967 INVENTORY OF AGRICULTURAL RESEARCH WAS SUMMARIZEO MANUALLY FROM INFORMATION IN CRIS PRIOR TO OPERATIONAL STATUS OF THE AUTOMATEO SYSTEM.

[5/] ESTIMATEO FIGURES INCLUOEO IN THE 1967 INVENTORY.

[6/] INCLUOES ALL USOA AGENCIES, SAES, FORESTRY SCHOOLS, ANO OTHER COOPERATING INSTITUTIONS.

DISTRIBUTION OF RESEARCH FUNDS BY CRIS RESEARCH PROBLEM AREA GOALS - FY 1968 TO 1975[1]
(MILLIONS OF CONSTANT DOLLARS)[2/3]

AGENCY GOAL[4]		FISCAL YEAR 1968	1969	1970	1971	1972	1973	1974	1975	PERCENT CHANGE 1968 TO 1975
ARS										
I	NATURAL RESOURCES	25.8	24.4	23.0	22.1	21.5	20.6	18.8	18.5	- 28.3
II	PROTECTION	55.3	54.6	49.8	51.8	54.7	50.4	48.6	47.2	- 14.6
III	PRODUCTION	29.2	28.7	35.1	35.7	36.0	36.7	35.4	37.0	26.7
	SUBTOTAL: II + III	84.5	83.3	84.8	87.5	90.7	87.1	83.9	84.2	- 0.4
IV	PRODUCTS, PROCESSES & QUALITY	46.5	43.6	42.1	40.9	38.4	37.0	33.9	31.3	- 32.4
V	MARKETING SYSTEMS	5.6	4.8	5.4	5.3	5.0	5.1	4.6	4.2	- 25.0
VI	EXPORTS & FOREIGN ASSISTANCE	.4	1.4	1.6	1.8	1.9	1.9	2.4	2.1	425.0
VII	HUMAN HEALTH & NUTRITION	14.0	15.1	17.1	19.5	20.1	19.6	20.2	19.7	40.7
VIII	RURAL LIVING	.5	.6	.7	.6	.5	0.4	0.4	0.5	0.0
IX	ENVIRONMENTAL IMPROVEMENT	6.6	7.1	10.4	11.6	14.5	15.0	14.6	14.0	112.1
OTHER		.3	.5	1.5	.1	--	.9	.1	.2	- 33.3
	SUBTOTAL: I + IV THRU OTHER	99.5	97.5	101.6	102.0	101.9	100.3	95.0	90.5	- 9.0
	TOTAL	184.0	180.8	186.5	189.6	192.6	187.4	178.9	174.7	- 5.1
NATIONAL TOTAL[5]										
I	NATURAL RESOURCES	72.6	72.8	73.4	73.1	72.0	70.4	71.0	73.7	1.5
II	PROTECTION	132.3	130.7	119.8	121.7	125.8	126.8	130.3	132.3	0.0
III	PRODUCTION	178.6	173.6	192.1	192.6	188.3	191.2	194.1	194.8	9.1
	SUBTOTAL: II + III	310.8	304.3	311.9	314.3	314.1	318.0	324.5	327.0	5.2
IV	PRODUCTS, PROCESSES & QUALITY	72.5	79.3	77.2	75.5	73.2	71.4	70.0	67.3	- 7.2
V	MARKETING SYSTEMS	24.9	23.9	24.3	24.1	23.3	22.6	22.8	22.6	- 9.2
VI	EXPORTS & FOREIGN ASSISTANCE	3.5	4.4	4.7	5.6	5.6	5.0	5.1	5.3	51.4
VII	HUMAN HEALTH & NUTRITION	27.8	29.6	31.0	31.8	33.7	35.1	35.8	36.7	32.0
VIII	RURAL LIVING	11.9	14.3	13.1	14.5	13.2	13.5	13.2	13.3	11.8
IX	ENVIRONMENTAL IMPROVEMENT	34.8	37.7	43.4	49.6	56.3	60.2	63.4	64.7	85.9
OTHER		42.5	46.0	41.9	39.4	35.7	31.3	24.5	31.3	- 26.4
	SUBTOTAL: I + IV THRU OTHER	290.5	308.1	309.0	313.7	313.0	309.4	305.8	314.9	8.4
	TOTAL	601.3	612.4	621.1	628.0	627.1	627.4	630.3	641.9	6.8
DEFLATORS[2]		.774	.812	.864	.929	1.000	1.069	1.157	1.283	

[1] DATA SUMMARIZED FROM THE INVENTORY OF AGRICULTURAL RESEARCH FROM THE CURRENT RESEARCH INFORMATION SYSTEM (CRIS).

[2] DEFLATORS ARE FOR FEDERAL PURCHASES OF GOODS AND SERVICES, P.191, ECONOMIC REPORT OF PRESIDENT 1977.

[3] SUMS OF INDIVIDUAL ITEMS MAY NOT AGREE WITH COLUMN TOTALS BECAUSE OF ROUNDING.

[4] SEE PAGES xiv-xvii OF INVENTORY OF AGRICULTURAL RESEARCH, VOL. 11, 1975, FOR MORE COMPLETE DESCRIPTION OF GOALS.

[5] INCLUDES ALL USDA AGENCIES, SAES, FORESTRY SCHOOLS, AND OTHER COOPERATING INSTITUTIONS.

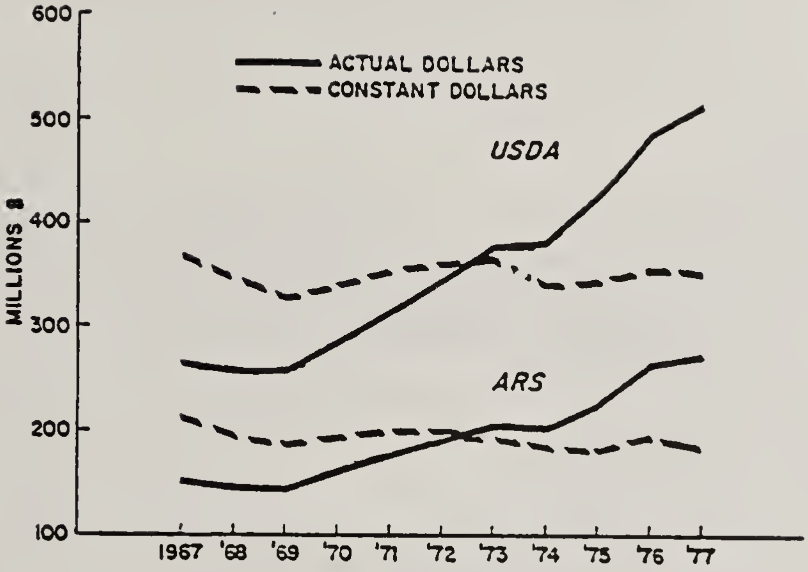


Figure 1. USDA and ARS R&D Appropriations

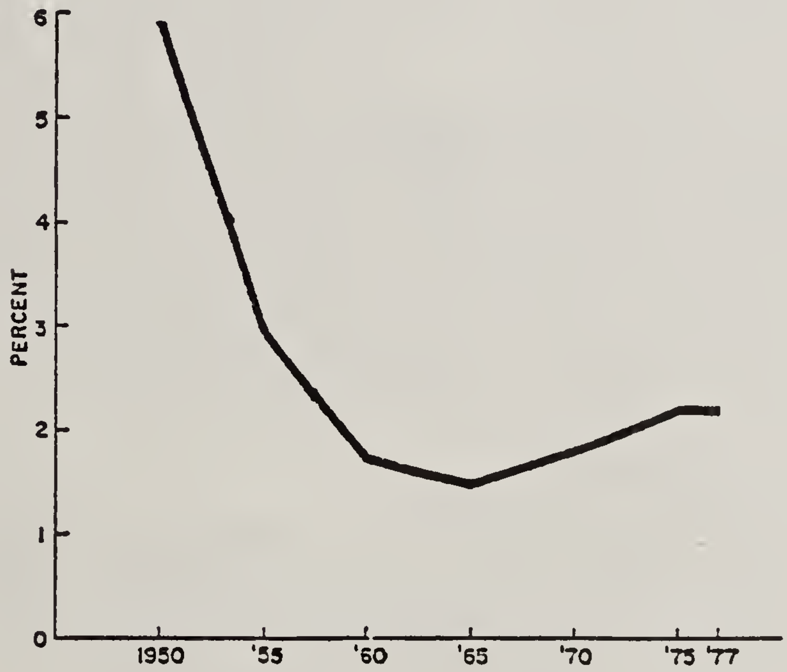


Figure 2. USDA Share in Federal R&D

Data Source: Survey of Science Resources Series, National Science Foundation

Research Need Areas in Order of Rating by Delegates.
(Numbers in parentheses identify need areas as listed in Table 1.1 and elsewhere.)

	Average rating
Energy (3.4)	4.73
Soybeans: Production (5.1P)	4.58
Water (3.2)	4.53
Basic problems in plant growth and reproduction (16.0)	4.51
Nutrient requirements (1.1)	4.45
Production inputs and services (13.1)	4.43
International development: Food production Technology and resource management (15.1)	4.43
Land (3.1)	4.42
Corn: Production (4.3P)	4.35
Wheat: Production (4.1P)	4.32
Dairy: Production (10.1P)	4.32
Beef: Production (9.1P)	4.31
Public policy: Domestic (14.1)	4.31
Vegetable crops: Production (6.1P)	4.31
Aquatic food sources: Production (10.3P)	4.29
Public policy: International (14.2)	4.28
Food technology (2.1)	4.28
Production systems (13.2)	4.27
Harvested forages and seed production: Production (8.1P)	4.24
Food safety (2.3)	4.19
Delivery systems: Education (1.4)	4.16
Nutrient composition (1.2)	4.16
International development: Food quality and distribution (15.2)	4.12
Poultry: Production (10.2P)	4.12
Pork: Production (9.2P)	4.11
Fruits and nuts: Production (7.1P)	4.10
Dry beans and peas: Production (6.3P)	4.08
Finance (14.3)	4.07
Soybeans: Consumer needs (5.1C)	4.07
Human resources (11.1)	4.06
Weather and climate (3.3)	4.06
Marketing systems (12.0)	4.04
International development: Economical, political, and institutional aspects of technology and resources (15.3)	4.02
Rice: Production (4.2P)	4.00
Permanent, rotation, and irrigation pastures:Production(8.2P)	3.99
Aquatic food sources: Marketing and processing (10.3M)	3.99
Range: Production (8.3P)	3.98
Potatoes: Production (6.2P)	3.96
Grain sorghum: Production (4.4P)	3.95
Corn: Marketing and processing (4.3M)	3.93
Delivery systems: Noneducation and food programs (1.5)	3.92
Social institutions (11.2)	3.90
Aquatic food sources: Consumer needs (10.3C)	3.90
Vegetable crops: Marketing and processing (6.1M)	3.89
Beef: Marketing and processing (9.1M)	3.88
Bees and other pollinating insects: Production (7.2P)	3.88
Dairy: Consumer needs (10.1C)	3.84
Food consumption (1.3)	3.83
Corn: Consumer needs (4.3C)	3.83
Poultry: Consumer needs (10.2C)	3.81
Dairy: Marketing and processing (10.1M)	3.79
Poultry: Marketing and processing (10.2M)	3.78
Nonconventional food sources (2.2)	3.78
Vegetable crops: Consumer needs (6.1C)	3.78
Fruits and nuts: Marketing and processing (7.1M)	3.76
Wheat: Marketing and processing (4.1M)	3.75
Wheat: Consumer needs (4.1C)	3.73

	Average rating
Lamb and mutton: Production (9.3P)	3.73
Pork: Marketing and processing (9.2M)	3.70
Sugar: Production (5.5P)	3.68
Soybeans: Marketing and processing (5.1M)	3.68
Cottonseed: Production (5.2P)	3.67
Barley, oats, and rye: Production (4.5P)	3.66
Other oilseeds: Production (5.4P)	3.63
Peanuts: Marketing and processing (5.3M)	3.62
Beef: Consumer needs (9.1C)	3.60
Peanuts: Production (5.3P)	3.58
Fruits and nuts: Consumer needs (7.1C)	3.57
Pork: Consumer needs (9.2C)	3.56
Grain sorghum: Marketing and processing (4.4M)	3.55
Potatoes: Marketing and processing (6.2M)	3.55
Dry beans and peas: Marketing and processing (6.3M)	3.53
Other oilseeds: Consumer needs (5.4C)	3.53
Sugar: Consumer needs (5.5C)	3.51
Peanuts: Consumer needs (5.3C)	3.51
Other animal products: Production (9.4P)	3.49
Dry beans and peas: Consumer needs (6.3C)	3.48
Rice: Marketing and processing (4.2M)	3.48
Cottonseed: Consumer needs (5.2C)	3.46
Lamb and mutton: Consumer needs (9.3C)	3.41
Sugar: Marketing and processing (5.5M)	3.41
Lamb and mutton: Marketing and processing (9.3M)	3.39
Bees and other pollinating insects: Consumer needs (7.2C)	3.39
Cottonseed: Marketing and processing (5.2M)	3.37
Other animal products: Marketing and processing (9.4M)	3.35
Other oilseeds: Marketing and processing (5.4M)	3.33
Bees and other pollinating insects: Marketing and processing (7.2M)	3.30
Potatoes: Consumer needs (6.2C)	3.26
Barley, oats, and rye: Marketing and processing (4.5M)	3.22

SUMMARY

Human needs	4.09
Organization of resources	4.17
Management of resources:	3.83
Natural resources	4.43
All commodities:	
Production	4.01
Marketing and processing	3.61
Consumer needs	3.58

Source: Research to Meet U.S. and World Food Needs, Report of a Working Conference sponsored by the Agricultural Research Policy Advisory Committee (ARPAC), Kansas City, Missouri, July 9-11, 1975. Volume I. (9)

SUMMARY: CURRENT SUPPORT AND RECOMMENDED INCREASES FOR MOST IMPORTANT PROBLEMS AND BARR AREAS - BY KANSAS CITY CONFERENCE CATEGORIES AND RESEARCH NEED AREAS a/

Research Need Area	Estimated Current SY 1/	Recommended Increase-SY
CATEGORY I HUMAN NEEDS FOR FOOD		
Nutrient Requirements (1.1)	146	112
Nutrient Composition (1.2)	117	50
Delivery Systems: Education (1.4)	21	43
Food Technology (2.1)	224	40
Food Safety (2.3)	114	60
CATEGORY I - TOTAL	622	305
CATEGORY II - ORGANIZATION OF RESOURCES TO PROVIDE FOOD		
Human Resources (11.1)	148	10
Public Policy: Domestic (14.1)	36	15
Public Policy: International (14.2)	81	15
Finance (14.3)	5 2/	1
International Development: Food Production Technology and Resource Management (15.1)	32 3/	55
International Development: Food Quality and Distribution (15.2)	-- 4/	--
International Development: Economic, Political and Institutional Aspects (15.3)	13	5
Production Inputs and Services (13.1)	42	5
Production Systems (13.2)	111	60
Marketing Systems (12.0)	114	25
CATEGORY II - TOTAL	582	191
CATEGORY III - MANAGEMENT OF RESOURCES TO PROVIDE FOOD		
Natural Resources		
Land (3.1)	476	80
Water (3.2)	339	114
Weather and Climate (3.3)	38	45
Energy (3.4)	177	169
Total, Natural Resources	1030	408

Source: U.S. Food Research, Report of Ad Hoc Work Group on Most Important Problems, May 1976. (15)

a/ Numbers in parenthesis identify need areas as listed in Table 1 of "U.S. Food Report," May 1976.

Research Need Area	Estimated Current SY 1/	Recommended Increase-SY
CATEGORY III - MANAGEMENT OF RESOURCES TO PROVIDE FOOD (continued)		
Crops		
Basic Problems in Plant Growth and Reproduction (16.0)	461	180
Crop Protection (BARR 12)	602 5/	80
Wheat: Production (4.1)	175	45
Rice: Production (4.2)	40	19
Corn: Production (4.3)	256	40
Soybeans: Production (5.1)	184	88
Vegetable Crops: Production (6.1)	418	80
Dry Beans & Peas: Production (6.3)	24	7
Forage and Range (8.0)	423	126
Other Crops	144	12
Total Crops	2125	677
Livestock		
Beef: Production (9.1)	435	60
Pork: Production (9.2)	189	30
Dairy: Production (10.1)	367	75
General Livestock Problems (BARR)	794 6/	270
Total, Livestock	1446	435
Aquatic Food Sources	101 7/	15 8/
CATEGORY III - TOTAL	4702	1535
Total - Most Important Problems and BARR Areas - USDA and State Agricultural Research Agencies	5906	2031

1/ Current SY's were for the most part obtained from the SY 1974 Data Base of Food and Food Related Research in USDA and State Research Agencies. A few, however, were estimated by members of the Ad Hoc Work Group from data in the Current Research Information System projects.
2/ Data not available on all Finance research. Estimate is for research in intergenerational transfer only.
3/ SY's directly related to foreign countries. Other related research with domestic objectives = 398 SY.
4/ Applicable research is in Category I.
5/ Included in other crop areas also; therefore, is not added to totals.
6/ Total is adjusted to account for 339 SY's that are also shown in 9.1, 9.2, and 10.1.
7/ Excludes 887 SY's in the U.S. Department of Commerce.
8/ U.S. Department of Commerce projects the need for a substantial increase in this area.

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